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APPENDIX A:

Reference list of DHI applications of the MIKE model to power plants and marine outfalls

POWER, DESALINATION AND INDUSTRIAL PLANTS

Hydraulic and Environmental Investigations by DHI

Project	Client	Year
Shin-Kori Nuclear Power Plant #3&4, Korea ROK. Development and optimisation of cooling water intake and discharge systems. Establishment of alternative discharge systems concepts followed by an analysis and ranking of alternatives. The analyses focused on hydraulic and constructability aspects, such as for example intake of fish and sediments, diffusion and recirculation characteristics, pressure losses through system, wave and current impact forces on diffusor heads, scour protection and occurrence of surges in the overall system during operational and non-operational conditions. The analyses were carried out by physical scale model tests in combination with numerical modelling.	Korea Power Engineering Co, Inc, Korea	2003-04
Shin-Wolsong Nuclear Power Plant #1&2, Korea ROK. Development and optimisation of cooling water intake and discharge systems. Establishment of alternative discharge systems concepts followed by an analysis and ranking of alternatives. The analyses focused on hydraulic and constructability aspects, such as for example intake of fish and sediments, diffusion and recirculation characteristics, pressure losses through system, wave and current impact forces on diffusor heads, scour protection and occurrence of surges in the overall system during operational and non-operational conditions. The analyses were carried out by physical scale model tests in combination with numerical modelling.	Korea Power Engineering Co, Inc, Korea	2003-04
Benghazi North Combined Cycle Power Plant, Libya. The work included marine survey works of topographical and bathymetrical survey, seawater and seabed sediment sampling, oceanographic and meteorological observations and marine soil investigations. The results of the marine survey works were used for a numerical study for recommendation of suitable layout of intake/outfall configuration and for assessment of the potential of cooling water recirculation.	Daewoo Engineering and Construction Co Ltd, Korea for General Electricity Company of Libya (GECOL)	2003

Project	Client	Year
Kashagan Field, Caspian Sea. The work included an assessment of the thermal and chemical impact of the Caspian Sea environment associated with an effluent discharge from an artificial D-block Island, planned for construction in 2003 as part of the development of Kashagan Field. Numerical recirculation study, assessment of the risk on the marine ecosystem of main chemicals, assessment of chemical additive's dosing plans and development of outline monitoring plans for controlling the dosage of inhibitors.	Agip Kazakhstan North Caspian Operating Company N. V.	2003
Shin-Kori Nuclear Power Plant #1&2, Korea ROK. Development and optimisation of cooling water dicharge system. Establishment of alternative discharge systems concepts followed by an analysis and ranking of alternatives. The analyses focused on hydraulic and constructability aspects, such as for example diffusion and recirculation characteristics, pressure losses through system, wave and current impact forces on diffusor heads, scour protection and occurrence of surges in the overall system during operational and non-operational conditions. The analyses were carried out by physical scale model tests in combination with numerical modelling.	Korea Power Engineering Co, Inc, Korea	2002
UAE, Fujairah Desalination and Power Plant. Conduct of 2D/3D mathematical modelling of discharge of brine (excess salinity) and heat to study potential recirculation and environmental impact associated with alternative discharge schemes and recommendation of most feasible scheme.	Fichtner GmbH & Co., UAE Offsets Group, Abu Dhabi	2001
Gulf Power Plant, Sirte, Libya, G.S.P.L.A.J. Technical feasibility analysis of alternative cooling water intake locations and systems for 1,400 MW thermal power plant.	General Electricity Company of Libya (GECOL)	2001
Zawiya Combined Cycle Power Plant, Libya, G.S.P.L.A.J. Marine hydraulic investigations for and conceptual design of cooling water intake and outfall structures. The investigations comprised establishment of design hydrographic conditions, thermal recirculation by numerical model assessment of littoral transport conditions and conceptual layout of intake and outlet structures and their relative locations.	General Electricity Company of Libya (GECOL)	2001
Seawater Intake at Seraya-2, Singapore. Physical modelling of intake and pump station aiming at optimising the intake structure in order to obtain good flow approach to the pumps.	Frederic R Harris BV, The Hague, The Netherlands	2000

Project	Client	Year
Power plant cooling water recirculation study, Bangladesh. 2D (MIKE 21) and 3D (MIKE 3) modelling of cooling water discharge with a view to recommend most feasible cooling water scheme in regards recirculation. Assessment of design current and flood levels for power plant platform.	AES Meghnaghat Combined Cycle Power Plant, Bangladesh	2000
Tampa Bay, Florida, USA. Study of near-field impact of a new desalination plant to be integrated with an existing power plant. The plant, when completed, will be the largest desal facility in the western hemisphere; and the largest in the world located in an estuary environment.	S & W Water, USA.	2000
Shoaiba Power Plant, Stage 1, Saudi Arabia (Red Sea coast). Hydraulic model tests (stability and wave tranquillity) for optimisation of detailed design of the discharge channel and jetty structures. *)*	Saudi Archirodon Ltd. (SARCO), Jeddah, Saudi Arabia	1999
Meghnaghat Power Station, Meghna River, Bangladesh. Study of near-field cooling water dilution, carried out in association with Surface Water Modelling Centre, Dhaka.	ESG International, Canada, representing AES Corporation, USA	1999
Haripur Combined Cycle Power Plant, Shitalakhya River, Bangladesh. Study of design water level, sedimentation, scour, bank protection stability, and recirculation, carried out in association with Surface Water Modelling Centre, Dhaka.	Hyundai Engineering & Construction Co., Republic of Korea	1999
Aluminium Bahrain. Heat and salt recirculation study and environmental impact assessment for a desalination plant built as a part of a coke calcining plant.	Aluminium Bahrain BSC (c)	1998
Meghnaghat Power Station, Meghna River, Bangladesh. Study of hydraulic design conditions, recirculation, stability of bank protection and effects of dredging, carried out in association with Surface Water Modelling Centre, Dhaka.	Mott Ewbank Preece (now: Mott MacDonald), UK, representing Bangladesh Power Development Board, funded by Asian Development Bank.	1997
King George and Queen Elizabeth Docks, Hull, UK. 3D modelling of heat and salinity budgets (considering a 33 percent evaporation loss) as a part of a feasibility study of utilising the docks for abstraction and disposal of cooling water for a new power plant.	ABP Research, UK, representing Energy Power Group, UK	1997
Hamburg Harbour, Germany. Numerical modelling of excess temperatures and recirculation for a cooling water discharge by linked 1D and 2D models of the Elbe River.	Deutsche Shell AG, Germany	1997
Juncker's Industries, Boiler 8, Denmark. Assessment of compliance with environmental standards, and prediction of mixing zone and impact area.	Juncker's Industries, Denmark	1997
Ruwais General Utilities Plant, Abu Dhabi. Analysis of marine data, identification of normal and adverse design periods, and recirculation analysis by 2D and 3D modelling	UAE.Fluor Mideast Ltd. (USA), representing Abu Dhabi National Oil	1996

Project	Client	Year
for an 81m³/s cooling water discharge.	Company	
Asnæs Power Plant, Denmark. Impact study of using a new bitumen-based fuel, Orimulsion: Surface drift of bitumen, impact on beaches, and entrainment into the cooling water system.	SK Energy, Denmark	1995
Amagerværket Power Plant, Denmark. Design of real-time marine monitoring system for the approach channel.	Copenhagen Harbour Authority, Denmark	1995
Avedøre Power Station Unit 2, Denmark. Hydraulic basis for EIA; modelling of entrainment of organisms, recirculation, and excess temperatures.	Elkraft A.m.b.A., Denmark	1995
KONTEK power transmission project, Denmark. A marine power transmission link between Denmark and Germany, using seawater as one conductor. Hydraulic basis for environmental feasibility and EIA, near-field chlorine concentrations, and marine monitoring.	SEAS, Denmark	1994-97
Sonelgaz Power Station, Port d'Alger, Algeria. Investigation of the intake temperature for a modified intake necessitated by a planned extension of the harbour.	Portconsult (Denmark)	1994
Al Khobar Power and Desalination Plant, Saudi Arabia. Hydraulic investigations for the Phase III extension. 3D modelling of recirculation.	LG Mouchel & Partners (UK) on behalf of Hitachi Zosen (Japan)	1994
Lumut Power Station, Malaysia. Investigation of intake temperature and sediment entrainment for an extension of the intake structure.	HYDEC, Malaysia, on behalf of Lumut Power Station	1994
Neka Power Plant, Iran. Hydraulic concept study for design modifications of cooling water intake and sedimentation basin.	Water Research Center Co., Teheran, Iran	1993
Gdansk Northern Harbour, Gdansk, Poland. Investigation of environmentally sustainable and economically feasible management options for disposal of coal fly ash.	Zespol Elektrocieplowni, Poland, ECII, and the Danish Environmental Protection Agency	1993
Central Termica de Santurce (Santurce Power Plant), Bilbao, Spain. Identification of feasible relocation of the cooling water intake and outfall after the extension of Port of Bilbao. 2D and 3D modelling of dispersion and recirculation.	Iberdrola S.A., Spain, represented by HIDTMA SL, Spain	1992-96
Yenshui-Kang Power Plant, Taiwan, ROC. Hydraulic investigations. Conceptual design of the marine cooling water system, recirculation analysis, and compliance with national environmental standards.	Taiwan Power Corporation	1992-94
Morocco Nuclear Power Plant. 2D and 3D modelling of cooling water recirculation.	Le Laboratoire Public d'Essais et d'Etudes, Morocco	1992
Køge Bay, Denmark. Study of fly ash disposal on reclaimed land. Leachate dispersal, navigational impact, coastal morphology.	Elkraft A.m.b. A, Denmark	1992

Project	*Client*	*Year*
Sellafield Nuclear Power Plant, UK. Mathematical modelling of wave climate, tide, recirculation, and sediment transport with 2D and 3D models.	British Nuclear Fuels PLC, Warrington, England	1992
Kelang Power Station, Malaysia. Recirculation study based on numerical modelling.	HYDEC, Malaysia	1992
Jeddah Power and Desalination Plant, Saudi Arabia. Numerical 2D and 3D modelling of cooling water and brine dispersal, recirculation, and interaction with adjacent plants.	Fichtner Consulting Engineers, Germany	1992
Masinloc Thermal Power Plant, Philippines. Numerical modelling of excess temperatures and solutes, model transfer and training.	National Power Corporation, Philippines, financed by Asian Development Bank	1991-93
Morocco Nuclear Power Plant, Morocco. Storm surge study, and mathematical, Morocco modelling of far-field excess temperatures.	Le Laboratoire Public d'Essais et d'Etudes, Morocco	1991
Petacalco Power Plant, Mexico. Numerical modelling of leachate dispersal of fly ash.	Comision Federal de Electricidad, Mexico	1991
Jubail Power and Desalination Plant, Saudi Arabia. Feasibility study and conceptual design of seawater system.	Saline Water Conversion Corporation, Saudi Arabia	1991
Ría del Ferrol, Spain. Study of dispersal of coal dust in the marine environment.	Empresa Nacional de Electricidad, Spain, represented by Rambøll & Hannemann, Denmark	1991
Barranco de Tirajana and Granadilla Power Plants, Gran Canaria and Tenerife, Spain. Specialist services during initial planning.	HIDTMA S.A., Spain, representing Unión Eléctrica de Canarias S.A., Spain	1991
Hsinta Power Plant, Taiwan, ROC. Physical and mathematical modelling of cooling water dispersal, conceptual design of outfall channel.	Taiwan Power Co.	1990
Taichung Thermal Power Plant, Taiwan, ROC. Thermal diffusion, sedimentation, and coastal erosion study.	Taiwan Power Co.	1988-89
Stigsnæsværket Power Plant, Denmark. Field survey, mathematical modelling, coastal hydraulics.	Elkraft, Denmark	1988-89
Masnedøværket Power Plant, Denmark. Field survey, mathematical modelling.	Elkraft A.m.b.A., Denmark	1988
Asnæsværket, Denmark. Study of hydraulic performance and environmental effects of a submerged intake.	Elkraft A.m.b.A, Denmark	1988
Hsinta Power Plant, Taiwan, ROC. Mathematical modelling of sediment transport and excess temperatures.	Sinotech Consulting Engineers, Taiwan, ROC	1987-89
Baseline study of cooling water dispersal for seven Danish coal-fired power plants.	Elkraft A.m.b.A., Denmark	1986-87

Project	*Client*	*Year*
Morocco Nuclear Power Plant, Morocco. Tsunami hindcasts, and mathematical modelling of near-field excess temperatures.	Le Laboratoire Public d'Essais et d'Etudes, Morocco	1986-87
Asnæsværket, Denmark. Environmental monitoring of cooling water dispersal and excess temperature distribution.	Elektricitetsselskabet Isefjordsværket, Denmark	1986
Fynsværket, Denmark. Study of cooling water system, recirculation, and environmental impact. Field survey, numerical modelling.	Elkraft A.m.b.A., Denmark	1986
Skærbækværket, Denmark. Study of recirculation, excess temperature distribution, and environmental impact.	Skærbækværket, Denmark	1986
Neka Power Plant, Iran. Study of intake basin.	Consortium Mazandaran (NEKA), Iran	1985-86
Al Taweelah Power and Desalination Plant, Abu Dhabi. Physical and mathematical modelling of excess temperatures and sediments.	Water and Electricity Dept., Abu Dhabi	1985-86
Taichung Thermal Power Plant, Taiwan ROC. Physical and mathematical modelling of cooling water dispersal.	Taiwan Power Co.	1985
Misurata Power and Desalination Plant, Libya. Surge study, environmental study. Field survey, physical and mathematical modelling.	Hyundai Engineering and Construction Co., Republic of Korea	1983-84
Barsebäckverket, Sweden. Evaluation of sedimentation in the intake basin of a nuclear power plant.	Sydsvenska Kraftaktiebolaget, Sweden	1983
Angra Nuclear Power Plant, Brazil. Wave study, dimensioning of marine structures.	Nuclebràs Engenharia S.A., Brazil	1982
Al Wusail, Ras Laffan, Al Qatar. Field survey, mathematical modelling, and site evaluation.	Fichtner Consulting Engineers, Federal Republic of Germany	1982
Enstedværket Power Plant, Denmark. Field survey, mathematical modelling, environmental hydraulics.	Sønderjyllands Højspændingsværk, Denmark	1981, 1985-86
Carboneras Power Station, Spain. Field survey, mathematical modelling, siltation and cooling water study.	PUCARSA S.A., Spain	1981-82
Kifunga Hydropower Plant, Tanzania. Specialist services during feasibility stage.	Greenland Technical Organization, financed by DANIDA	1981
Mecca Taif Power and Desalination Plant, Saudi Arabia. Field survey, mathematical modelling, location analysis.	Fichtner Consulting Engineers, Federal Republic of Germany	1981
Ras Tanajib Power and Desalination Plant, Saudi Arabia. Field survey, mathematical modelling.	Aramco Overseas Co., Holland	1981
Garden Island, Port Jackson, Australia. Numerical modelling of jet dilution and recirculation in a harbour basin.	Lawson and Treloar/Dept. of Construction and Housing, Commonwealth of Australia	1980

Project	*Client*	*Year*
Al Khobar Power and Desalination Plant, Saudi Arabia. Field survey, physical and mathematical modelling, long-term monitoring of marine environmental impact.	Hyundai Engineering and Construction Co., Republic of Korea	1979-83
Vendsysselværket Power Plant, Denmark. Field survey, mathematical modelling.	I/S Nordkraft, Denmark	1979-81
Vestkraft Power Plant, Denmark. Field survey, mathematical modelling, environmental hydraulics.	I/S Vestkraft, Denmark	1979-80
Amagerværket Power Plant, Denmark. Field survey, mathematical modelling, environmental hydraulics.	Elkraft, Denmark	1979-80, 1985
Ruwais Utility Intake, Abu Dhabi. Field survey, study of waves and sedimentation in cooling water intake channel.	Fichtner Consulting Engineers, Federal Republic of Germany	1979
Stevns Nuclear Power Plant, Denmark. Field survey, mathematical modelling, environmental hydraulics.	Elkraft, Denmark	1978-79
Ghazlan Power Plant, Saudi Arabia. Field survey, mathematical modelling.	Aramco Overseas Co., Holland	1978
H. C. Ørstedsværket Power Plant, Denmark. Field survey, mathematical modelling, environmental hydraulics.	Københavns Belysningsvæsen, Denmark	1978
St. Lucie Power Plant, USA. Review of cooling water dilution.	Florida Power and Light, USA	1978
Maracaibo Power Plant, Venezuela. Site investigation, cooling water study.	Inelectra S.A., Venezuela	1978
Avedøreværket, Denmark. Field survey, coastal and environmental impact, as part of feasibility analysis and detailed design of a power plant in Copenhagen.	Kraftimport I/S and Elkraft A.m.b.A, Denmark	1977, 1981-84
South Dade Power Plant, Florida. Hurricane study, hydraulic design basis.	Brown & Root, Inc., Texas, USA, on behalf of Florida Power and Light, USA	1997
Stigsnæs Power Plant, Denmark. Hydraulic concept evaluation of a deepwater cooling water intake.	SEAS, Denmark	1977
Kilroot Power Station, Northern Ireland. Wave study, physical model tests.	Christiani and Nielsen, Denmark	1975
Prai Power Station, Malaysia. Field investigations, recirculation study.	MINCO Ltd., Malaysia	1975
Gylling Næs Nuclear Power Plant, Denmark. Study of recirculation, environmental, and coastal hydraulic aspects.	Elsam, Denmark	1974-77
Barsebäckverket, Sweden. Hydrographic monitoring during dredging operations for a nuclear power plant.	Sydsvenska Kraftaktiebolaget, Sweden	1972

Project	Client	Year
Barsebäckverket, Sweden. Hydraulic concept evaluation of intake and other marine structures, mapping of excess temperature distribution and cooling water plume dilution, and hydraulic model tests for design of cooling water intake and sedimentation basin for a nuclear power plant.	Sydsvenska Kraftaktiebolaget, Sweden	1969-70

APPENDIX B:

Report on calibration of wave hindcast data by Fugro Oceanor

PRDW South Africa

Calibration of Wave Spectra in 3 Positions off South Africa

Fugro OCEANOR Reference No: C55162 / rev 0
2008-03-10

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Calibration of Wave Spectra in 3 positions off South Africa: C55162 / rev 0				
Rev	**Date**	**Originator**	**Checked & Approved**	**Issue Purpose**
	2008-03-10	G. Mørk	S. F. Barstow	FINAL

Rev 0 – 2008-03-10	**Originator**	**Checked & Approved**
Signed:		

This report is not to be used for contractual or engineering purposes unless the above is signed where indicated by both the originator of the report and the checker/approver and the report is designated ‘FINAL’.

TABLE OF CONTENTS

SUMMARY

Time series of 15 years of wave spectra from the ECMWF WAM model for three positions off South Africa have been calibrated against available satellite altimeter data. The calibration procedure is described, and a comparison between calibrated wave heights and altimeter ground truth is given. Plots of time series of wave parameters derived from the spectra are presented.

All the calibrated data (wave spectra and time series of overall wave parameters) have been supplied to the client as text files.

1. Introduction

The purpose of the present report is to document the validation and calibration of time series of wave spectra for three locations off South Africa, at positions

S 34.0°, E 18.0°	W of Cape Town
S 35.0°, E 19.0°	WSW of Cape Agulhas
S 35.0°, E 24.5°	SW of Port Elisabeth

The time series span the period from 1990-11 to 2007-10 (inclusive). However, the two year period 1991-06 to 1993-05 are left out of the series, so that a total of 15 years of data is supplied in each point. A discussion on the data quality is given, and plots of some wave parameters are presented.

2. Data Sources

Two types of data have been used: Model data and satellite altimeter data.

2.1 WAM data

The basic source of data is the directional wave spectra data from the WAM (“WAve Model”) model run at the European Centre for Medium Range Weather Forecast (ECMWF). We have used 15 (effective) year series of spectra from WAM, merged from two types of WAM data:

- *ERA-40* (“Ecmwf ReAnalysis 40 year”) is a WAM hindcast series. In principle, this series should be as homogeneous as possible, because the same version of the wave model is used throughout the 40 years. However, in order to provide as accurate data as possible, satellite altimeter, SAR and scatterometer data have been assimilated into the model according to its availability (from 1991). This affects the homogeneity, with data after 1993 being more accurate. Unfortunately, ECMWF assimilated faulty altimeter data into the simulations for the period 1991-12 / 1993-05, and the quality of this 18-month period is therefore significantly lower than the rest of the series. (In 2007, ECMWF finished a rerun of the analysis for this period with corrected altimeter data. However, the new corrected hindcast is not yet released, as of December 2007.) To avoid the low-quality part of the hindcast, we have left out a full two year of the series. We have thus used ERA-40 data for the period 1990-11-01 / 1998-06-28, leaving out the gap from 1991-06 to 1993-05 (inclusive).

- The other type of WAM data comes from the *operational model*. As the operational model is steadily modified, the accuracy of these data has steadily become even better. In a study in the central North Sea we compared the operational WAM data against a long series from a buoy, and were able to demonstrate that there was a steadily decreasing scatter index and increasing correlation coefficient of the WAM wave heights relative to buoy data. We have used operational WAM data for the period 1998-06-29 / 2007-10-31.

The quality of the basic ECMWF data is due, first, to the fact that ECMWF has attracted some of the best European wave and atmospheric modellers. Secondly, the assimilation of over 20 different satellite-borne sensors into the model suite in recent years is unique and undoubtedly the main reason for the high level of accuracy attained on a global basis. This is particularly important in areas with sparse data, such as the Southern Ocean from which much of Chilean swell energy derives.

As part of the calibration procedure, the spectra were integrated to derive the following wave parameters:

- Significant wave height Hm0
- Mean wave direction MDir
- Peak direction at the peak period ThTp
- Peak period Tp
- Mean (energy) wave period Tm-10
- Mean wave period Tm01
- Mean wave period Tm02 (zero up-crossing period)

The spectral resolution (i.e. number of frequencies and number of directions) changes throughout the time series as shown in the table below:

Model type and spectral resolution

Data type	*Start date*	*End date*	*Frequencies*	*Directions*
ERA-40	1990-11-01	1998-06-28	25	12
Operational	1998-06-29	2000-11-20	25	12
Operational	2000-11-20	2007-10-31	30	24

The delivered spectra have a temporal resolution of 6 hours, starting on 1990-11-01 T00, and ending on 2007-10-31 T18. As mentioned above, there is a gap in the series between 1991-05-31 T18 and 1993-06-01 T00. The ERA-40 data are given on a 1.5° grid, whereas the operational data are given on a 0.5° grid.

2.2 Satellite altimeter data

As of December 2007, data are available from the following satellite missions:

- *TOPEX* (from the US/French TOPEX/Poseidon mission). This satellite has been the most successful altimeter mission, delivering high quality data from September 1992 until late 2005. In August – September 2002 the satellite was moved to a new orbit, midway between its old ground tracks. (We have referred to these separate phases as TPX 1 and TPX 2, respectively, before and after its orbit change.)
- The *JASON* satellite was launched into the old TOPEX orbit when TOPEX was moved, and may be considered as a “Topex Follow-On”. It has been delivering data from September 2002.

- *GEOSAT* was operative between 1986 and 1989, and is thus not relevant in the present project. Later on, *GFO* ("Geosat Follow-On") was launched into the same orbit, and delivered data from January 2000.
- *EnviSat* from the European Space Agency (ESA) has been delivering data from October 2002.

The altimeter data (wave height and wind speed) from all the missions have been calibrated against a number of offshore buoys (mainly US, Canadian and Indian), and can be considered to have similar accuracy to buoy measurements.

We have used altimeter data from TOPEX (both TPX 1 and TPX 2), JASON, GFO and EnviSat for calibration of the wave spectra. Figure 1 shows a map of the area, with (approximate) satellite ground tracks and positions of the extracted altimeter data.

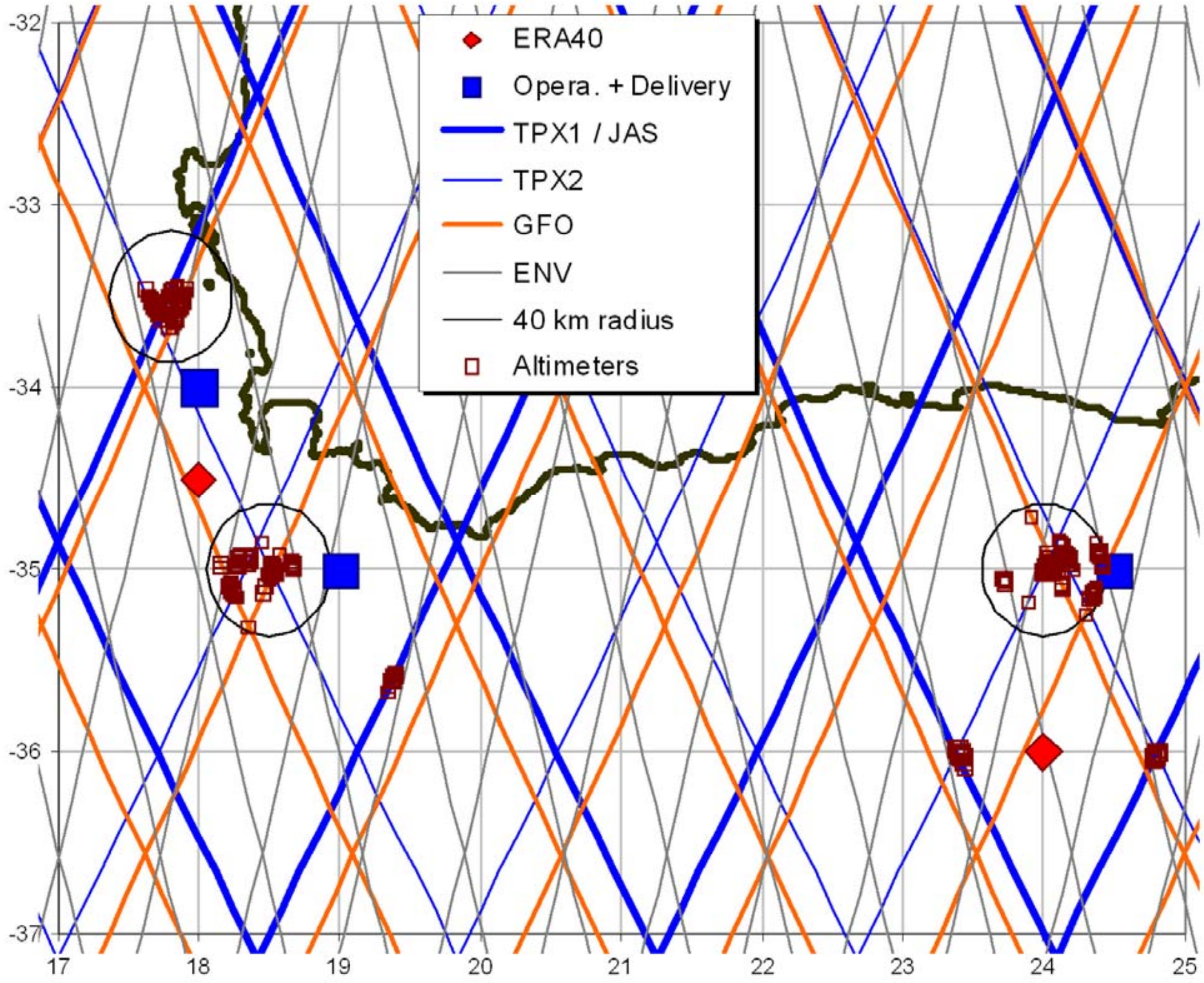

Figure 1 Map of the area with satellite tracks, positions of altimeter data and model data.

3. Calibration and validation

We used the altimeter data from all the available missions as the “ground truth” for calibrating the WAM data. Satellite altimeter data are extracted around the point in question. In practical terms, this means that each time the satellite passes (once every 10 – 35 days, depending on satellite), altimeter data are extracted for a location as close to the requested position as possible. Figure 1 shows the positions of the extracted altimeter data, as well as (approximate) ground tracks for the satellites.

The overall wave height is then matched and validated against the altimeter data, and a regression line is fit to the data. We have used QQ-regression lines (Quantile-Quantile graphs) to match the distributions as close to each other as possible. (This amounts to sorting each of the data series, plotting the sorted data against each other, and fitting a standard linear y-on-x regression line to the QQ-graph.) The linear regression lines are used to adjust the wave heights deduced from the spectra. The deduced wave periods are not adjusted and are left as is. Comparisons elsewhere show that this is a good assumption (apart from the period with faulty altimeter data referred to above).

Data from ERA-40 and the Operational data were validated and calibrated separately, as they may have different bias. As none of the requested positions lies on the 1.5° grid, spectral data from ERA-40 has to be obtained from a nearby position. In addition, only TPX1 can be used to calibrate ERA-40, because only TPX1 operated in the ERA-40 data period.

Target point	*Source point ERA-40*	*Source point Operational*
S 34.0°, E 18.0°	S 34.5°, E 18.0°	same as target
S 35.0°, E 19.0°	S 34.5°, E 18.0°	same as target
S 35.0°, E 24.5°	S 36.0°, E 24.0°	same as target

Note that, for the two westernmost target points, the ERA-40 data are taken from the *same* source point. However, the source data are adjusted differently, to “tune” them to the altimeter data relevant for the different target points. This means that, for these two positions (and up to 1998-06-28), the calibrated data will have the same directions and wave periods, but have different wave heights.

When satellite data were extracted to be used as ground truth, the positions were chosen primarily to be as close as possible to the target point. However, the water depth was also taken into account, to extract data, as far as possible, at approximately the same depth as the target point.

The different target positions are calibrated as follows (see Figure 1):

Target point	*Method*
S 34.0°, E 18.0° W of Cape Town	Altimeter data from TPX1, JASON, TPX2, GFO and EnviSat are extracted NW of the target position, and at approximately the same depth. Both the ERA-40 and the operational data are calibrated by means of altimeter data around this position.
S 35.0°, E 19.0° WSW of Cape Agulhas	Altimeter data from TPX2, GFO and EnviSat are extracted just W of the target position, and used to calibrate the operational data. Altimeter data from TPX1 and JASON are extracted on the track SE of the target, at approximately the same depth. These data are used to calibrate the ERA-40 data.
S 35.0°, E 24.5° SW of Port Elisabeth	Altimeter data from TPX2, GFO and EnviSat are extracted just W of the target position, and used to calibrate the operational data. The ERA-40 data are calibrated in two steps: (1) Altimeter data from TPX1 and JASON are extracted at latitude S 36°, and used to estimate non-biased data *at this latitude*. (2) The GFO satellite is used to estimate the difference between wave heights at latitudes S 36° and S 35°. The calibrated non-biased data from S 36° are then adjusted for the horizontal gradient to give non-biased data representative of latitude S 35°.

Figure 2 to Figure 6 show scatter plots of calibrated Hm0 versus altimeter measurements. A QQ-graph is shown on each figure, together with a corresponding white regression line and its formula. Boxes on the figures also give the number of points n, the correlation coefficient (rho), the root mean square error (RMSE) and mean values of the altimeter and model data. The RMSE has been estimated as

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_{1,i} - x_{2,i}\right)^2}$$

where point no i in the scatter plot has coordinates $\left(x_{1,i}\ ,\ x_{2,i}\right)$. Although it is not given on the figures, one useful goodness-of-fit parameter may be estimated as the so-called Scatter Index = RMSE/Mean.

A summary of the some statistical parameters is given below: (Note that the regression line in Figure 5 should not be y = x, because the calibrated model data is representative of latitude S 35°, whereas the altimeter data are for S 36°.)

Target point	*Model*	*Correlation*	*RMSE (m)*	*Scatter Index (RMSE / Mean x)*
S 34.0°, E 18.0°	ERA40 + Operational	0.925	0.392	15.2%
S 35.0°, E 19.0°	ERA40	0.852	0.642	20.0%
S 35.0°, E 19.0°	Operational	0.936	0.395	13.3%
S 35.0°, E 24.5°	ERA40	0.909	0.633	18.8%
S 35.0°, E 24.5°	Operational	0.856	0.737	22.7%

Figure 7 to Figure 12 present time series plots of wave parameters deduced from the calibrated spectra. (The thick orange lines are the monthly means.) For each target position, there are two figures: One with significant wave height Hm0, mean direction MDir and peak direction at peak wave period ThTp. The second figure displays wave periods: Peak period Tp, mean period Tm-10 (= energy period) and mean period Tm02 (= Tz, zero up-crossing period). Note that the last wave period is the one most sensitive to the high-frequency part of the spectrum.

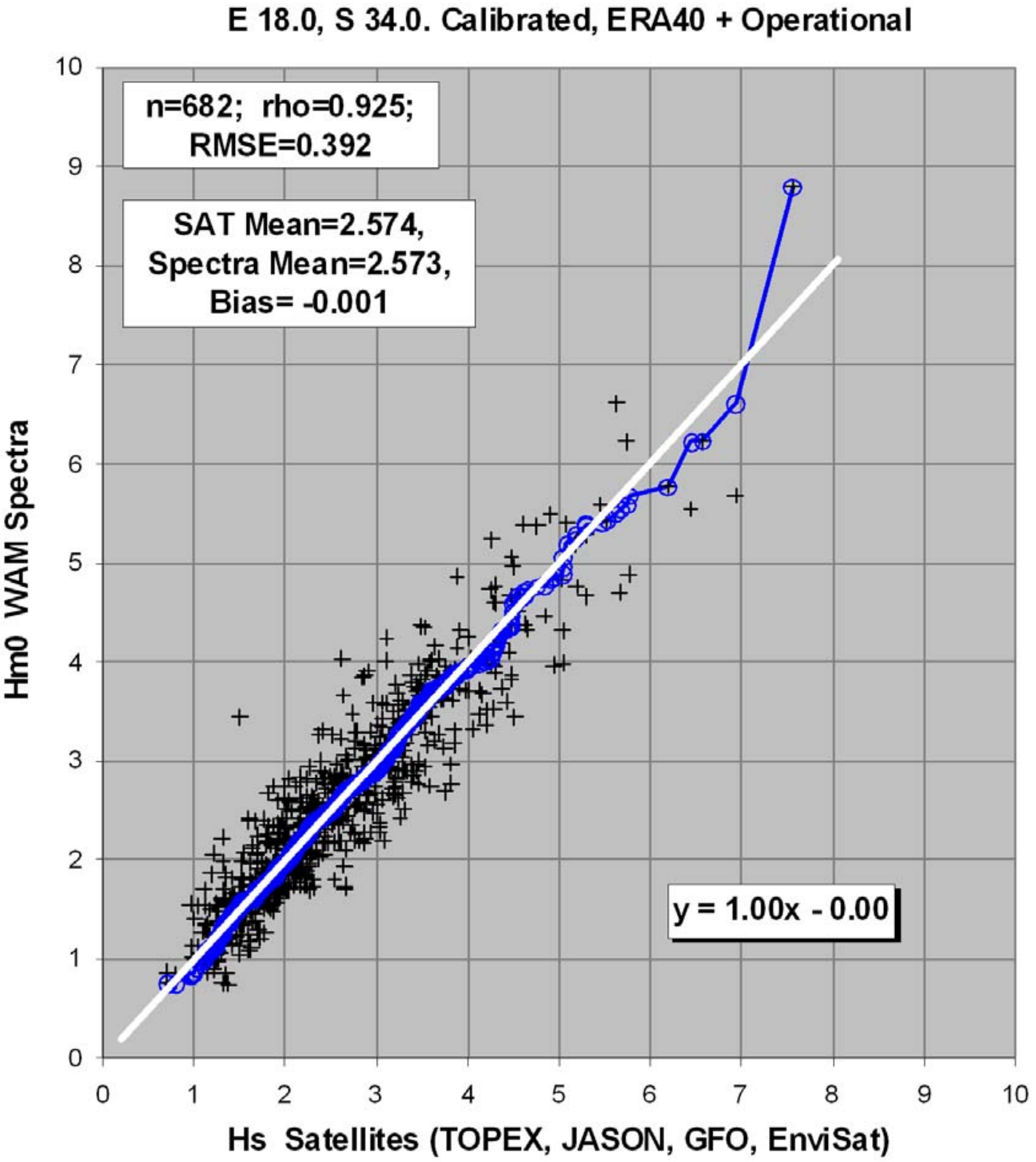

Figure 2 S 34.0°, E 18.0°, ERA-40 + Operational. Validation of calibrated Hm0 versus altimeter data. Black crosses are actual data, blue line is QQ-graph, with white regression line.

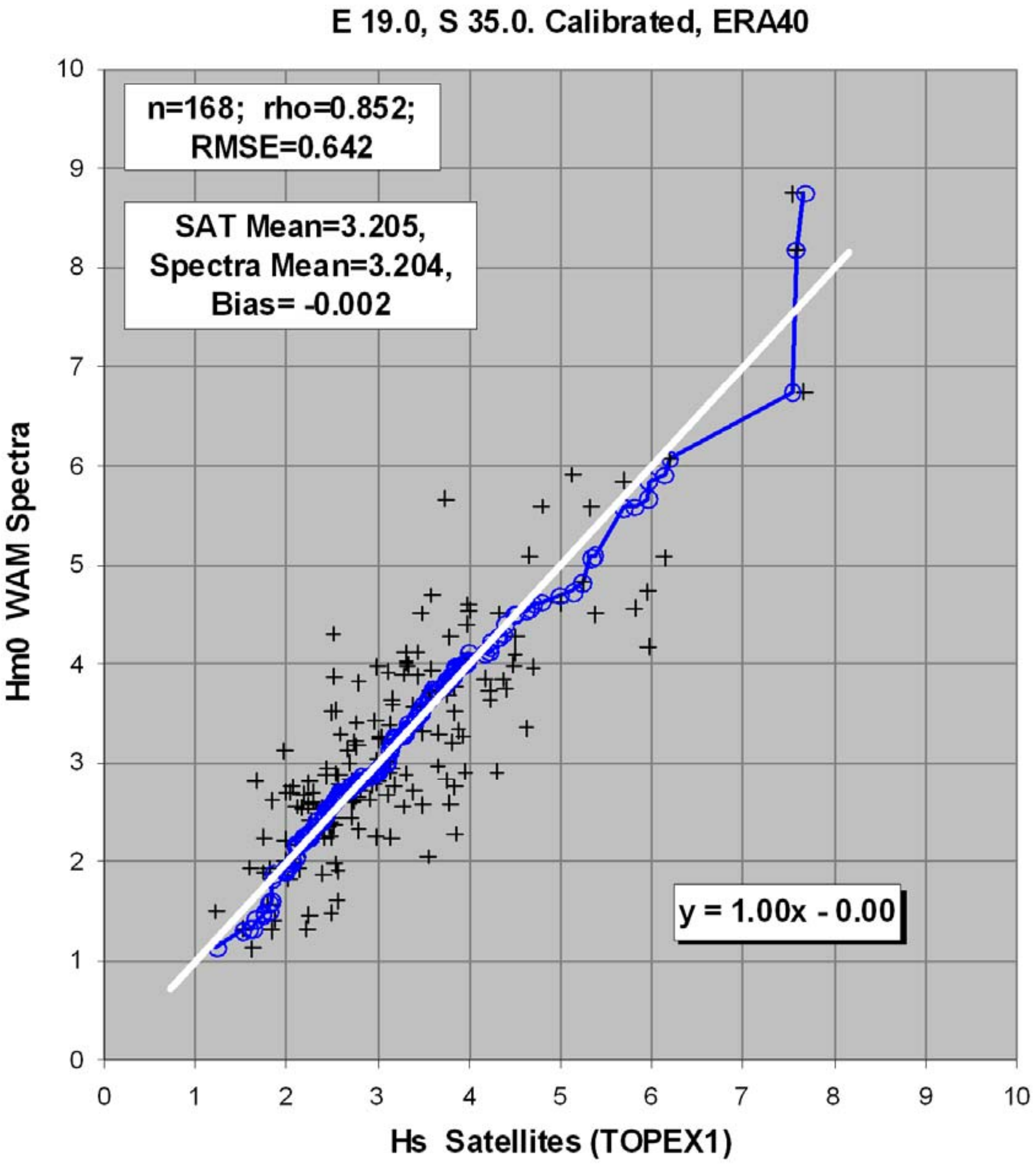

Figure 3 S 35.0°, E 19.0°, ERA-40. Validation of calibrated Hm0 versus altimeter data. Black crosses are actual data, blue line is QQ-graph, with white regression line.

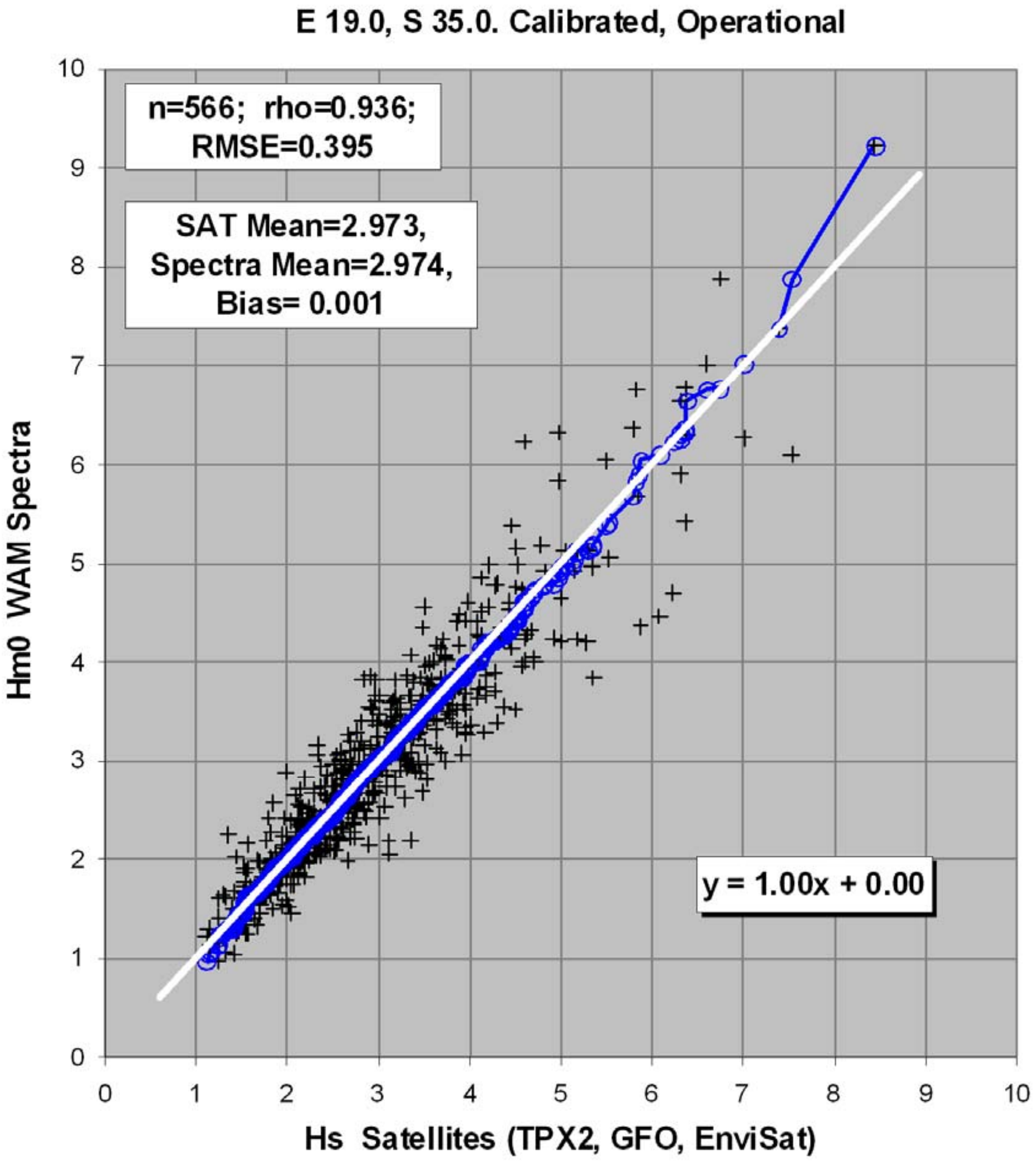

Figure 4 S 35.0°, E 19.0°, Operational. Validation of calibrated Hm0 versus altimeter data. Black crosses are actual data, blue line is QQ-graph, with white regression line.

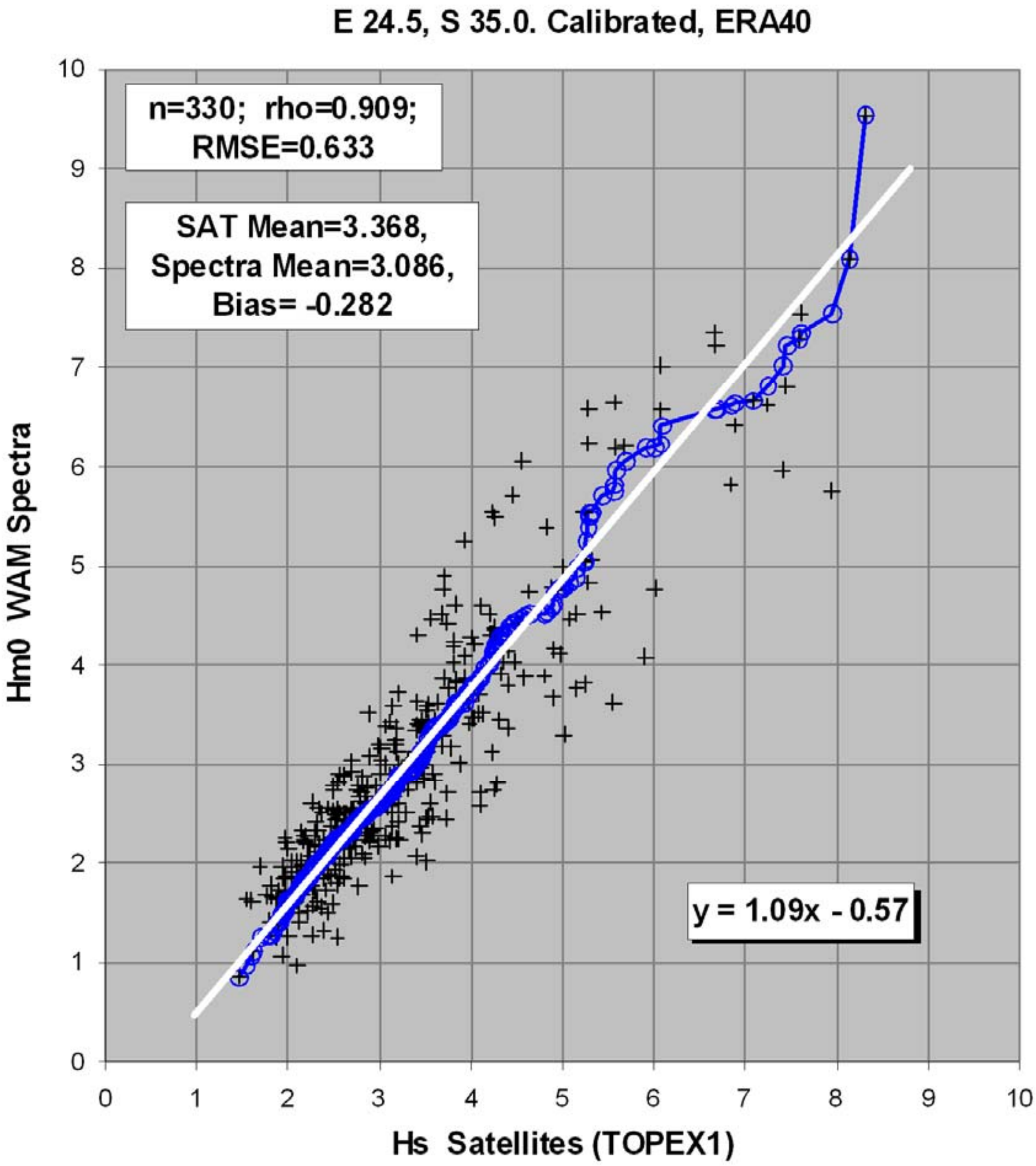

Figure 5 S 35.0°, E 24.5°, ERA-40. Validation of calibrated Hm0 versus altimeter data. Black crosses are actual data, blue line is QQ-graph, with white regression line. (Note: Altimeter data applies to S 36°, spectra data to S 35°.)

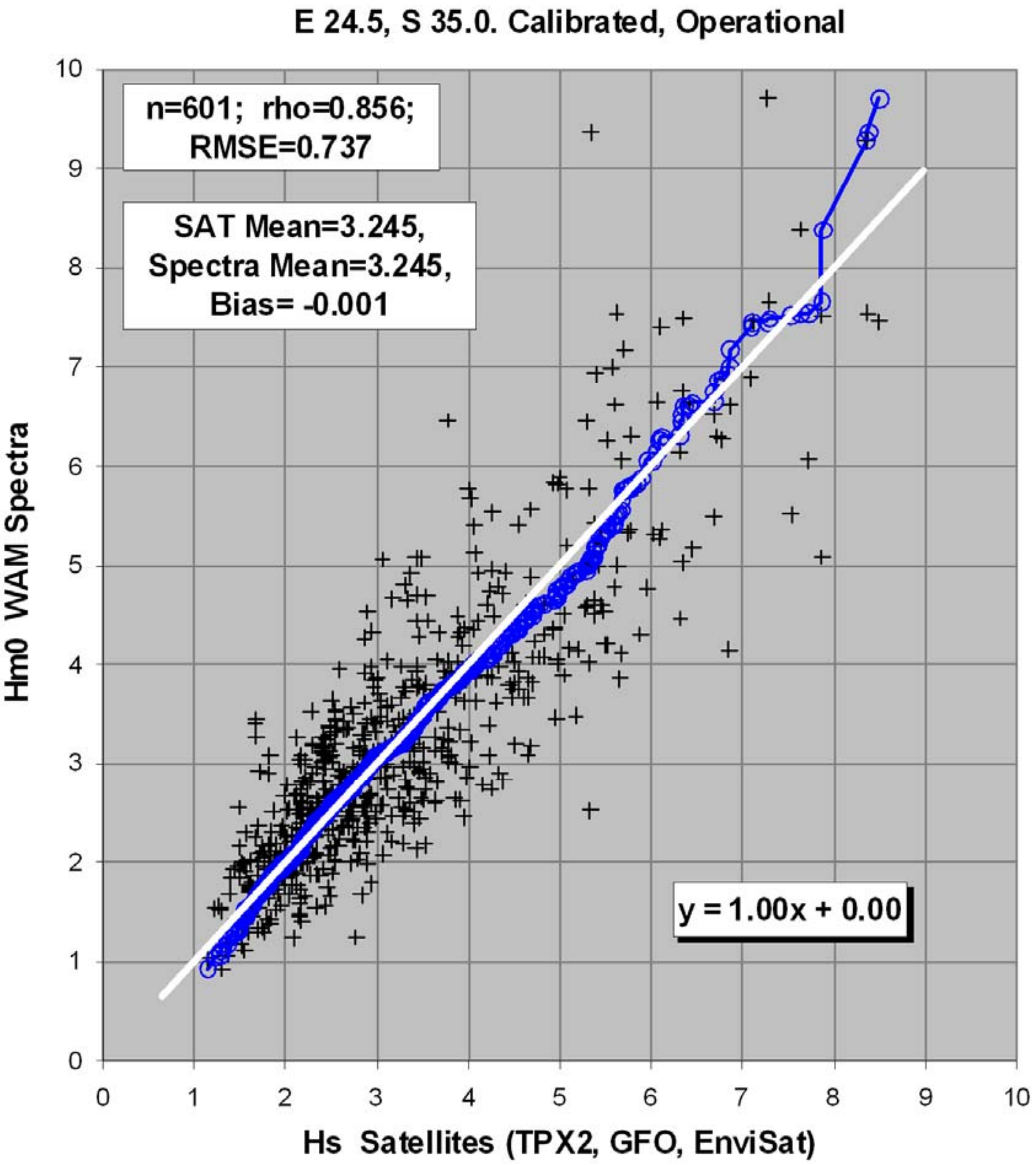

Figure 6 S 35.0°, E 24.5°, Operational. Validation of calibrated Hm0 versus altimeter data. Black crosses are actual data, blue line is QQ-graph, with white regression line.

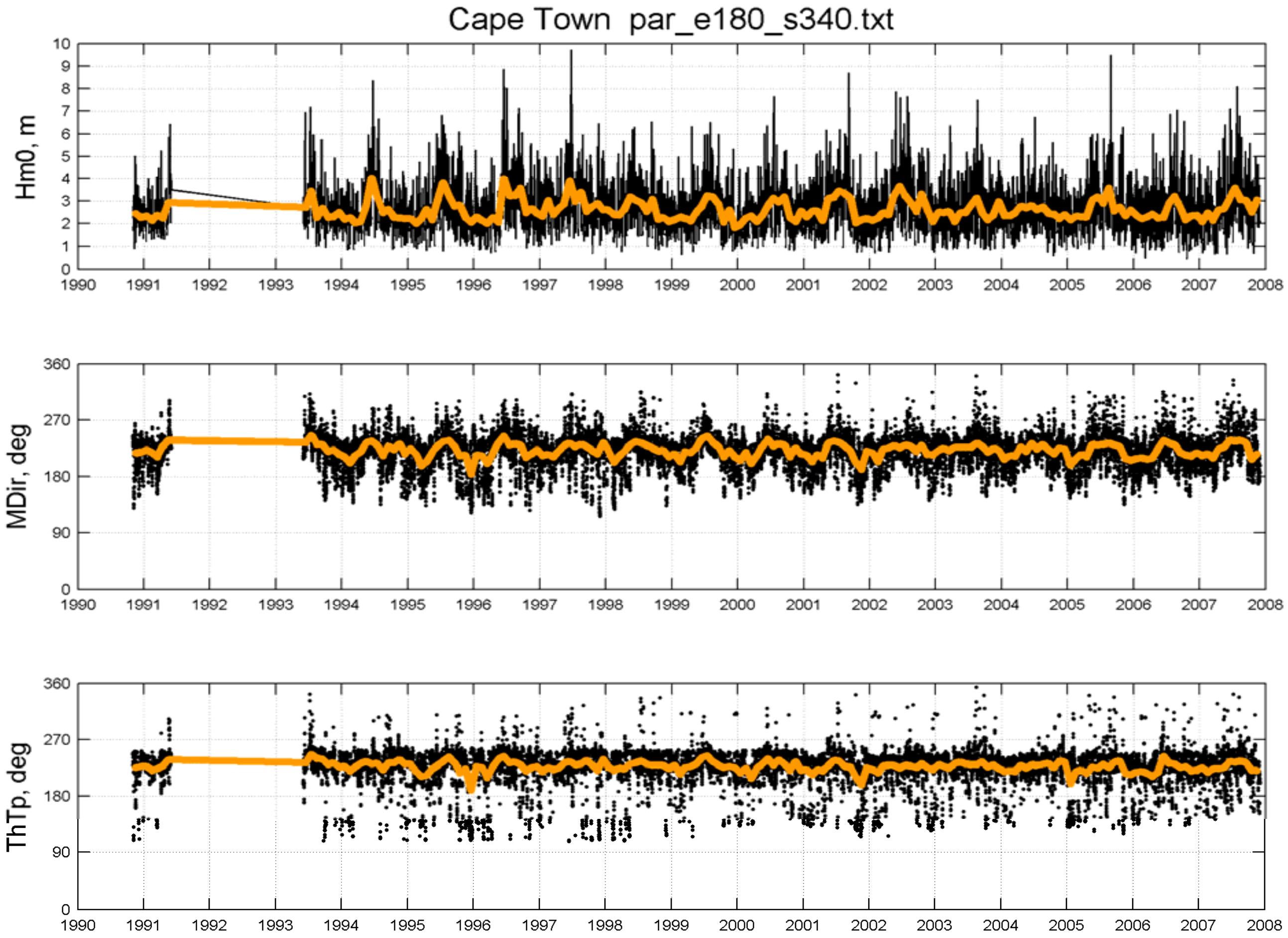

Figure 7 Time series of significant wave height and directions. S 34.0°, E 18.0°.

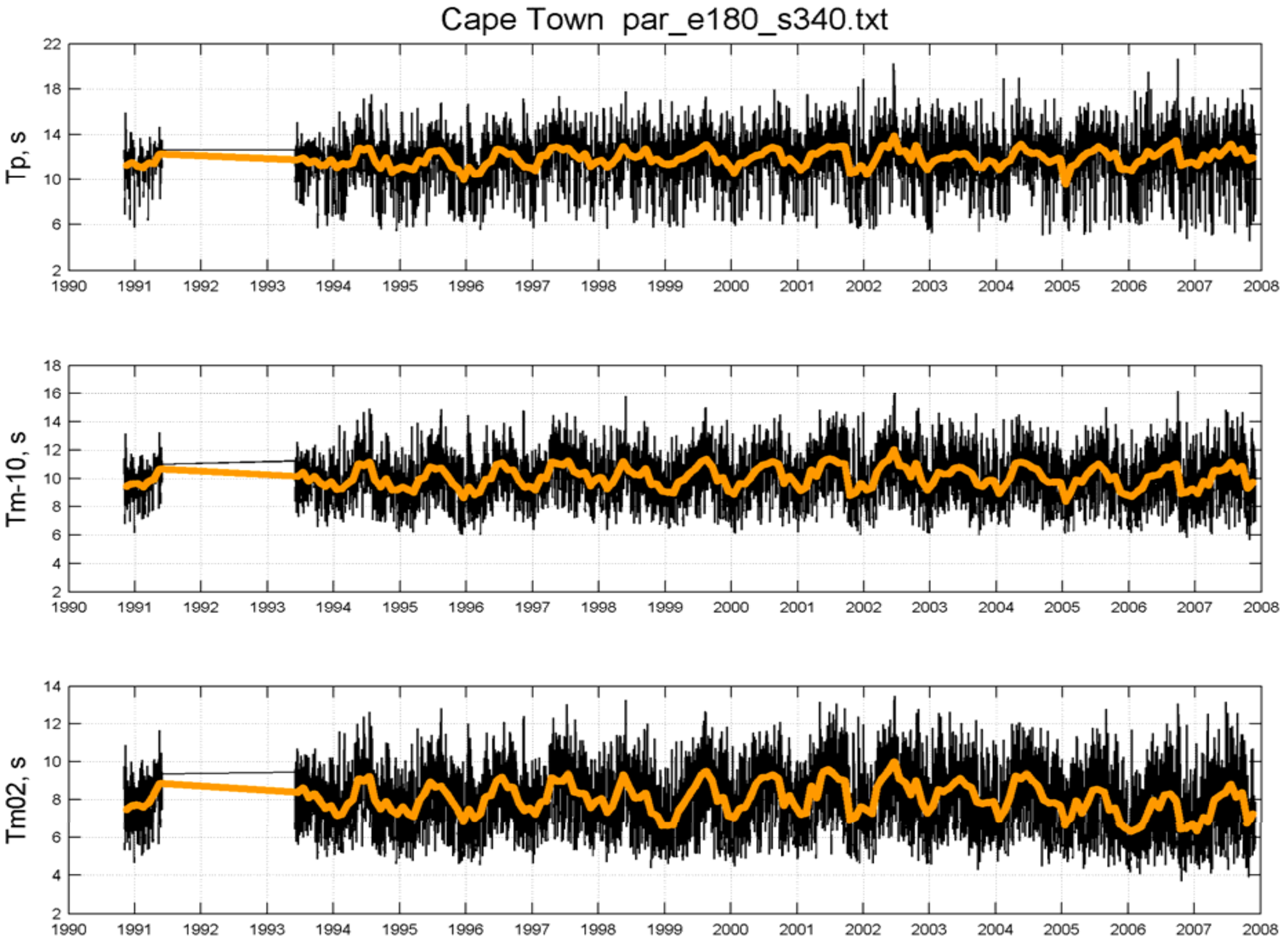

Figure 8 Time series of wave periods. S 34.0°, E 18.0°.

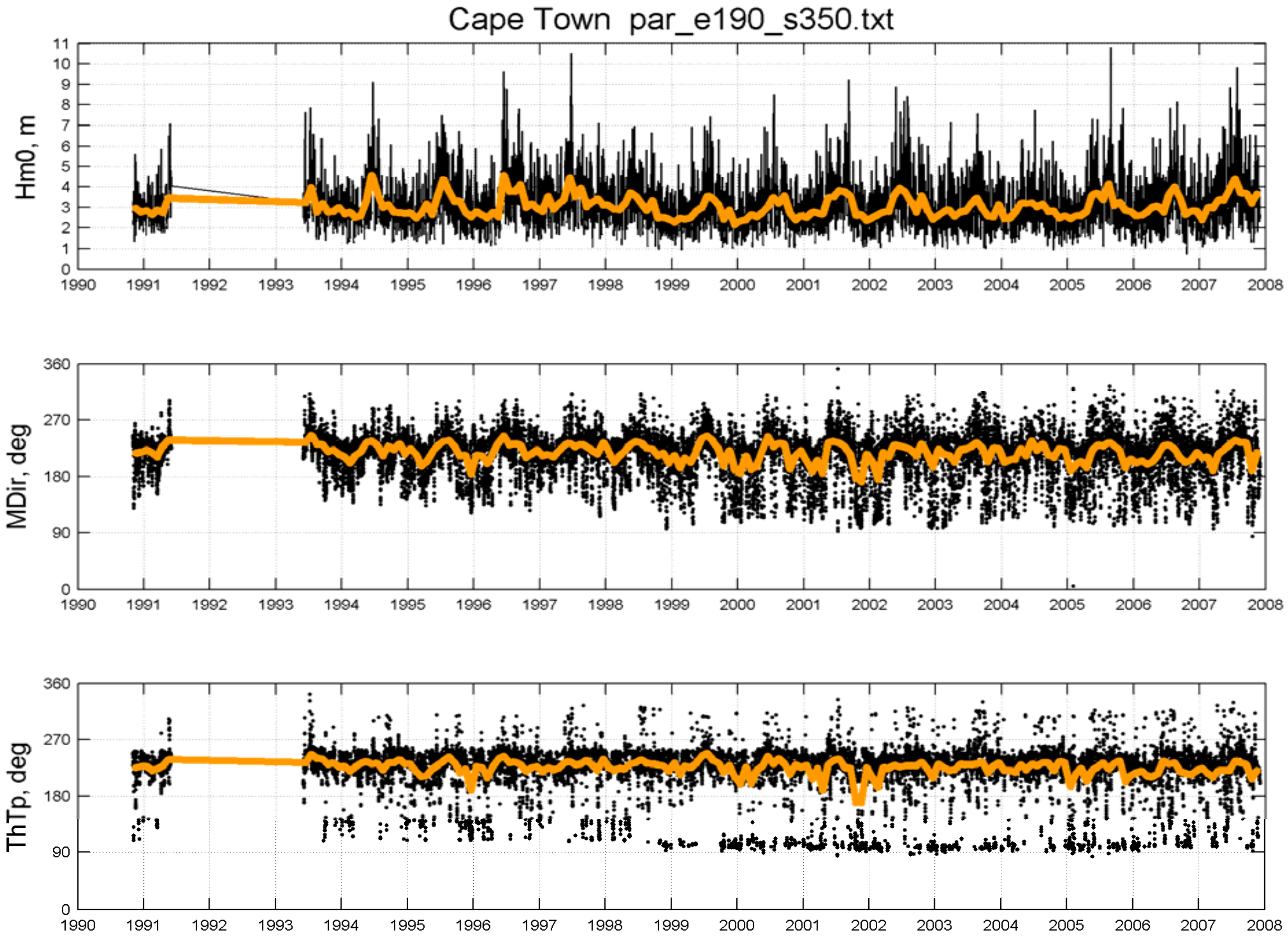

Figure 9 Time series of significant wave height and directions. S 35.0°, E 19.0°.

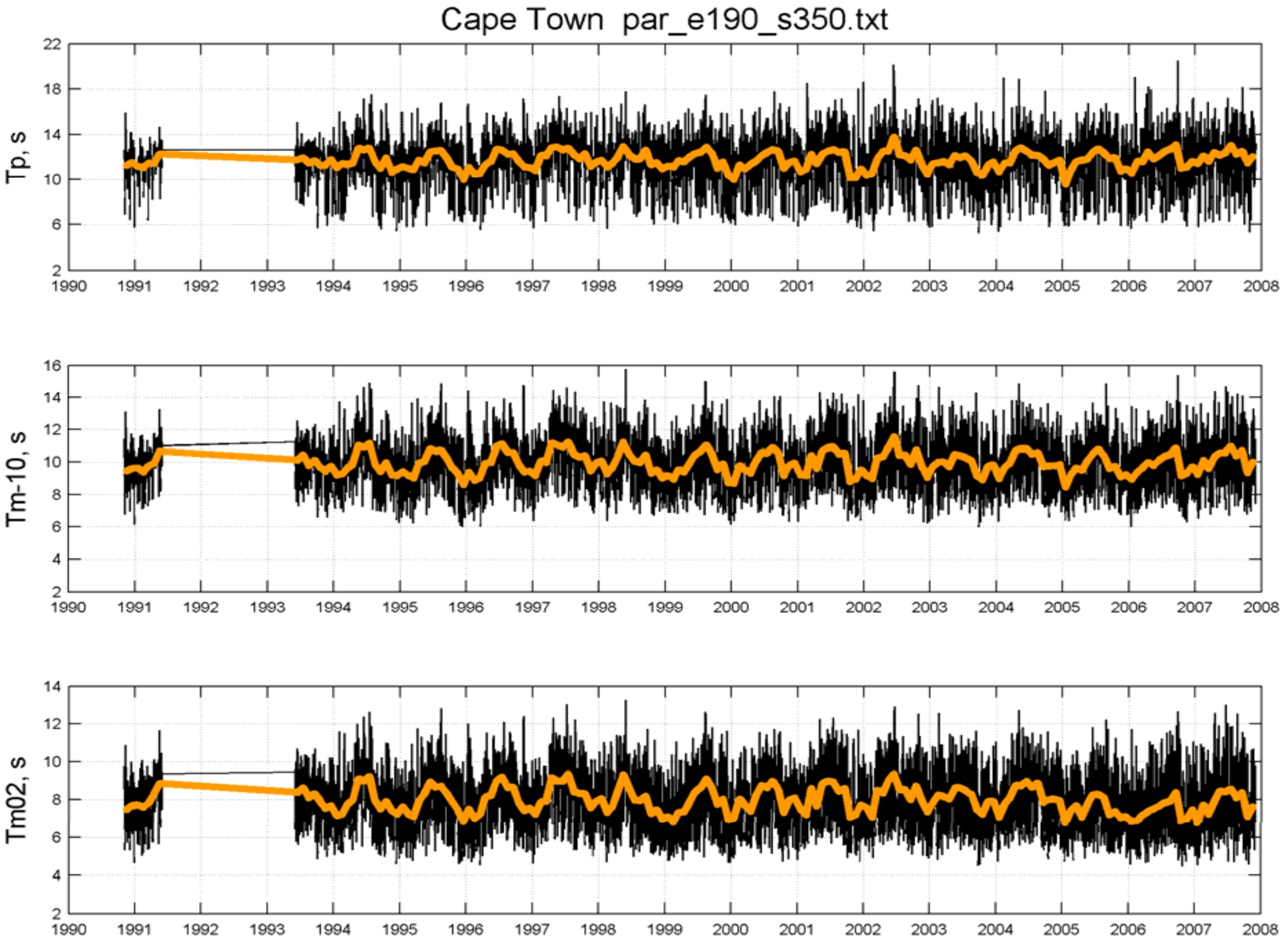

Figure 10 Time series of wave periods. S 35.0°, E 19.0°.

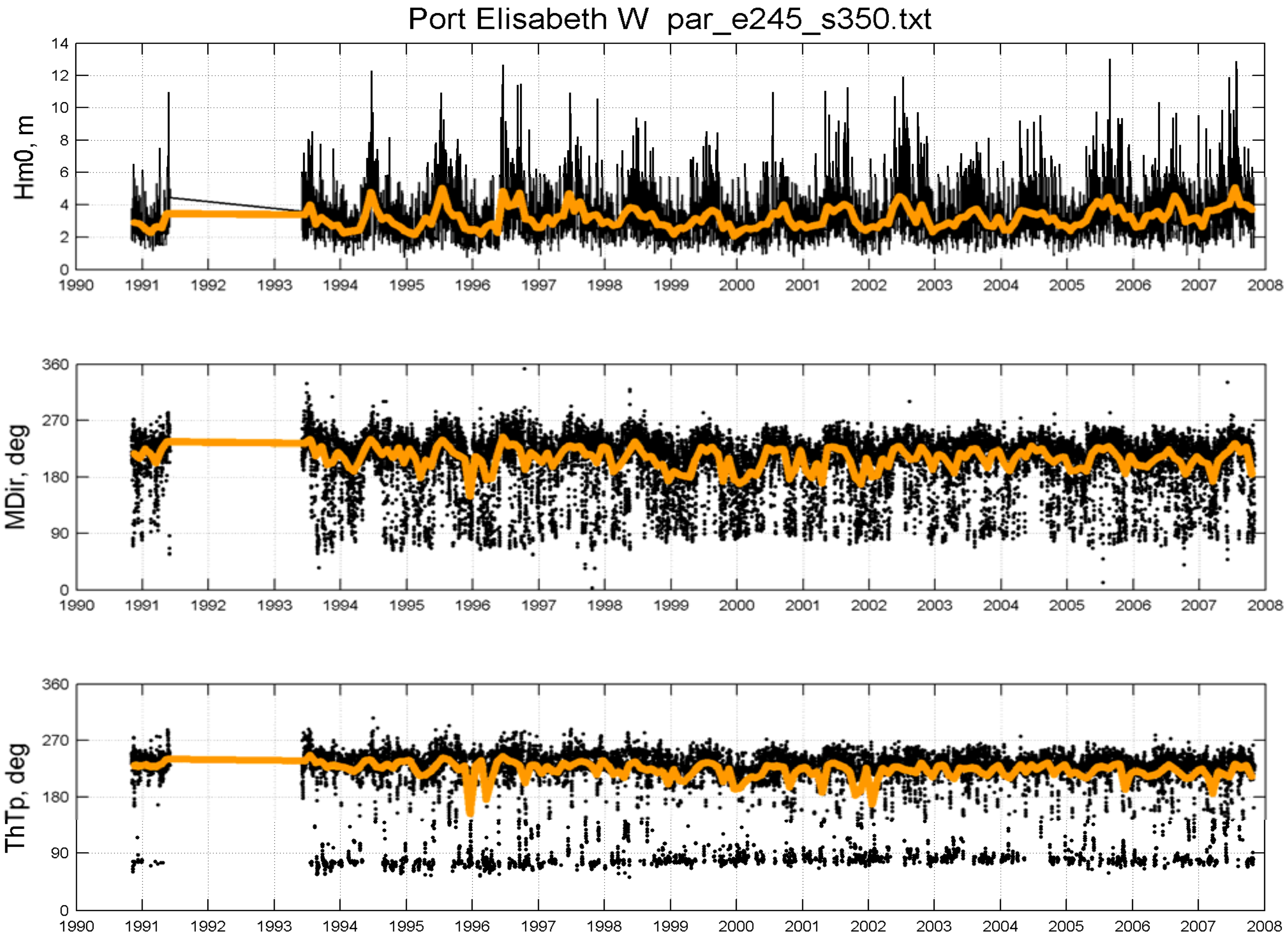

Figure 11 Time series of significant wave height and directions. S 35.0°, E 24.5°.

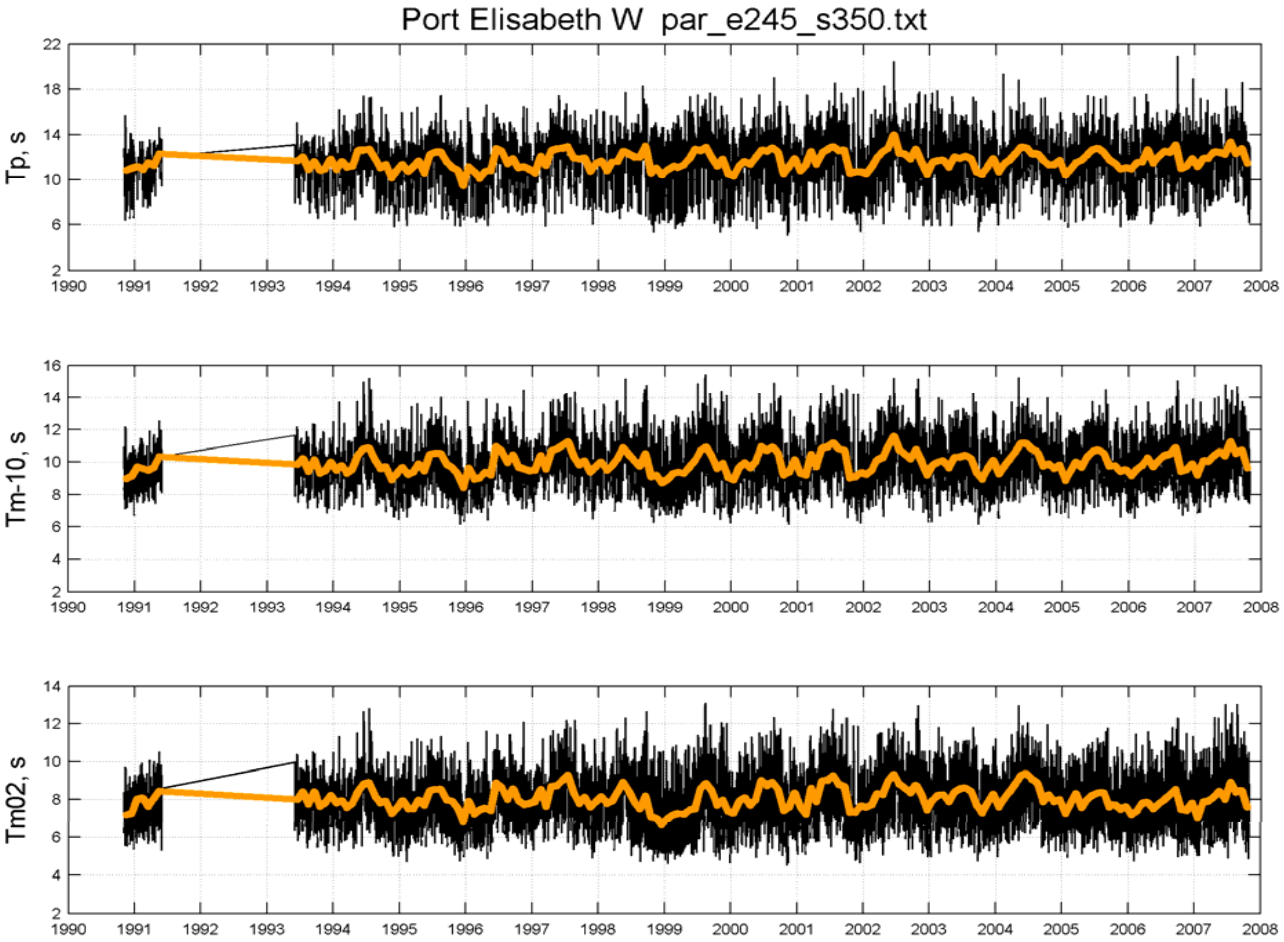

Figure 12   Time series of wave periods. S 35.0°, E 24.5°.

APPENDIX C:

Council for Geoscience Report: A Probabilistic Tsunami Hazard Assessment for Coastal South Africa from Distant Tsunamogenic areas

Revision 2

A Probabilistic Tsunami Hazard Assessment for Coastal South Africa from Distant Tsunamogenic areas

By

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Report No. 2008 – 0156

CONFIDENTIAL

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Definition of Terms, Symbols and Abbreviations

Acceleration	The rate of change of particle velocity per unit time. Commonly expressed as a fraction or percentage of the acceleration due to gravity (g), where $g = 9{,}81$ m/s^2.
Acceleration Response Spectra (ARS)	Spectral acceleration is the movement experienced by a structure during an earthquake.
Annual Probability of Exceedance	The probability that a given level of seismic hazard (typically some measure of ground motions, e.g., seismic magnitude or intensity), or seismic risk (typically economic loss or casualties)
Area-specific mean seismic activity rate (λ_A)	Mean rate of seismicity for the whole selection area in the vicinity of the site for which the PSHA is performed.
Attenuation	A decrease in seismic-signal amplitude as waves propagate from the seismic source. Attenuation is caused by geometric spreading of seismic-wave energy and by the absorption and scattering of seismic energy in different earth materials.
Attenuation law (relationship)	A mathematical expression that relates a ground motion parameter, such as the peak ground acceleration, to the source and propagation path parameters of an earthquake such as the magnitude, source-to-site distance, fault type, etc. Its coefficients are usually derived from statistical analysis of earthquake records. It is a common engineering term for a ground motion relation.
b-value (*b*)	A coefficient in the frequency-magnitude relation, $\log N(m) = a - bm$, obtained by Gutenberg and Richter (1941; 1949), where m is the earthquake magnitude and $N(m)$ is the number of earthquakes with magnitude greater than or equal to m. Estimated *b*-values for most seismic zones fall between 0,6 and 1,1.
Capable fault	A mapped fault that is deemed a possible site for a future earthquake with magnitude greater than some specified threshold.
Catalogue	A chronological listing of earthquakes. Early catalogues were purely descriptive, i.e., they gave the date of each earthquake and some description of its effects. Modern catalogues are usually quantitative, i.e., earthquakes are listed as a set of numerical parameters describing origin time, hypocenter location, magnitude, focal mechanism, moment tensor, etc.
CGS	Council for Geoscience
Power Plant ping	In vibration analysis, a term that indicates the mechanism for the dissipation of the energy of motion. Viscous Power Plant ping, which is proportional to the velocity of motion and is described by linear equations, is used to define different levels of response spectra and is commonly used to approximate the energy dissipation in the lower levels of earthquake response.
Design Earthquake	The postulated earthquake (commonly including a specification of the ground motion at a site) that is used for evaluating the earthquake resistance of a particular structure.
Elastic design spectrum (or spectra)	The specification of the required strength or capacity of the structure plotted as a function of the natural period or frequency of the structure and of the Power Plant ping appropriate to earthquake response at the required level. Design spectra are often composed of straight line segments (Newmark and Hall,

	1982) and/or simple curves, for example, as in most building codes, but they can also be constructed from statistics of response spectra of a suite of ground motions appropriate to the design earthquake(s). To be implemented, the requirements of a design spectrum are associated with allowable levels of stresses, ductilities, displacements or other measures of response.
Earthquake	Ground shaking and radiated seismic energy caused most commonly by sudden slip on a fault, volcanic or magmatic activity, or other sudden stress changes in the Earth.
Epicenter	The epicenter is the point on the earth's surface vertically above the hypocenter (or focus).
Epicentral distance (Δ)	Distance from the site to the epicenter of an earthquake.
Fault	A fracture or fracture zone in the Earth along which the two sides have been displaced relative to one another parallel to the fracture. The accumulated displacement may range from a fraction of a meter to many kilometres. The type of fault is specified according to the direction of this slip. Sudden movement along a fault produces earthquakes. Slow movement produces aseismic creep.
Focal depth (h)	Focal depth is the vertical distance between the hypocentre and epicentre.
Frequency	The number of cycles of a periodic motion (such as the ground shaking up and down or back and forth during an earthquake) per unit time; the reciprocal of period. Hertz (Hz), the unit of frequency, is equal to the number of cycles per second.
Ground motion	The movement of the earth's surface from earthquakes or explosions. Ground motion is produced by waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the earth and along its surface.
Ground motion parameter	A parameter characterizing ground motion, such as peak acceleration, peak velocity, and peak displacement (peak parameters) or ordinates of response spectra and Fourier spectra (spectral parameters).
Heterogeneity	A medium is heterogeneous when its physical properties change along the space coordinates. A critical parameter affecting seismic phenomena is the scale of heterogeneities as compared with the seismic wavelengths. For a relatively large wavelength, for example, an intrinsically isotropic medium with oriented heterogeneities may behave as a homogeneous anisotropic medium.
Hypocenter	The hypocenter is the point within the earth where an earthquake rupture starts. The epicenter is the point directly above it at the surface of the Earth. Also commonly termed the focus.
Hypocentral distance (r)	Distance from the site to the hypocenter of an earthquake.
Induced earthquake	An earthquake that results from changes in crustal stress and/or strength due to man-made sources (e.g., underground mining and filling of a high Power Plant), or natural sources (e.g., the fault slip of a major earthquake). As defined less rigorously, “induced” is used interchangeably with “triggered” and applies to any earthquake associated with a stress change, large or small.

Local Magnitude (M_L)	A magnitude scale introduced by Richter (1935) for earthquakes in southern California. M_L was originally defined as the logarithm of the maximum amplitude of seismic waves on a seismogram written by the Wood-Anderson seismograph (Anderson and Wood, 1925) at a distance of 100 km from the epicenter. In practice, measurements are reduced to the standard distance of 100 km by a calibrating function established empirically. Because Wood-Anderson seismographs have been out of use since the 1970s, M_L is now computed with a simulated Wood-Anderson records or by some more practical methods.
Magnitude	In seismology, a quantity intended to measure the size of earthquake and is independent of the place of observation. Richter magnitude or local magnitude (M_L) was originally defined in Richter (1935) as the logarithm of the maximum amplitude in micrometers of seismic waves in a seismogram written by a standard Wood-Anderson seismograph at a distance of 100 km from the epicenter. Empirical tables were constructed to reduce measurements to the standard distance of 100 km, and the zero of the scale was fixed arbitrarily to fit the smallest earthquake then recorded. The concept was extended later to construct magnitude scales based on other data, resulting in many types of magnitudes, such as body-wave magnitude (m_b), surface-wave magnitude (M_S), and moment magnitude (M_W). In some cases, magnitudes are estimated from seismic intensity data, tsunami data, or duration of coda waves. The word "magnitude" or the symbol *M*, without a subscript, is sometimes used when the specific type of magnitude is clear form the context, or is not really important.
Maximum Regional Earthquake Magnitude ($m_{\max}$)	Upper limit of magnitude for a given seismogenic zone or entire region. Also referred to as the maximum credible earthquake (MCE).
Operating Basis Event (OBE)	Event with an average return period in the order of 145 years i.e. 50 % probability of exceedance in 100 years.
Oscillator	In earthquake engineering, an oscillator is an idealized damped mass-spring system used as a model of the response of a structure to earthquake ground motion. A seismograph is also an oscillator of this type
Parameter of the distribution of ln(PGA) (γ)	$\gamma = \beta/c_2$, where $\beta = b$ ln(10) [see "***b*-value**"] , and c_2 is a coefficient related to the attenuation relationship.
Peak Ground Acceleration (PGA)	The maximum acceleration amplitude measured (or expected) of an earthquake.
Probabilistic Seismic Hazard Analysis (PSHA)	Available information on earthquake sources in a given region is combined with theoretical and empirical relations among earthquake magnitude, distance from the source and local site conditions to evaluate the exceedance probability of a certain ground motion parameter, such as the peak acceleration, at a given site during a prescribed period.
Response spectrum	The response of the structure to a specified acceleration time series of a set of single-degree-of-freedom oscillators with chosen levels of viscous damping, plotted as a function of the undamped natural period or undamped natural frequency of the system. The response spectrum is used for the prediction of the earthquake response of buildings or other structures.
Seismic Hazard	Any physical phenomena associated with an earthquake (e.g., ground motion, ground failure, liquefaction, and tsunami) and

	their effects on land use, man-made structure and socio-economic systems that have the potential to produce a loss. It is also used without regard to a loss to indicate the probable level of ground shaking occurring at a given point within a certain period of time.
Seismic Wave	A general term for waves generated by earthquakes or explosions. There are many types of seismic waves. The principle ones are body waves, surface waves, and coda waves.
Seismic zone	An area of seismicity probably sharing a common cause.
Seismogenic	Capable of generating earthquakes.
Site-specific mean activity rate (λ_S)	Mean activity rate of the selected ground motion parameter experienced at the site.
Strong ground motion	A ground motion having the potential to cause significant risk to a structure's architectural or structural components, or to its contents. One common practical designation of strong ground motion is a peak ground acceleration of 0.05g or larger.

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1. Introduction

The Council for Geoscience (CGS) was requested to provide probabilistic seismic hazard analyses (PSHA) for the areas of Calcutta, Karachi, South Sandwich and Sumatra. It is assumed that these are tsunamogenic areas, which can produce tsunami generating earthquakes that can affect coastal areas of South Africa. The objective of the PSHA is to obtain long-term probabilities of the occurrence of ground motion of a specified size in a given time interval. Several mutations of are known. The Parametric-Historic PSHA procedure is applied in this work as described by Kijko and Graham (1998; 1999), Kijko (2004), (Appendix A).

The results are given in terms of mean return periods and probabilities of being exceeded, for specified earthquake magnitudes. Appendices C, D, E and F show the results of the calculations for each of the areas. These contain details of the computations, input data and respective hazard parameters.

2. The Area-Specific Hazard

The area-specific parameters that have to be determined, i.e. the mean seismic activity rate (λ_A), the Gutenberg-Richter parameter (b) and the maximum possible earthquake magnitude ($m_{\max}$), are obtained by application of the K-S-B procedure (Kijko and Graham, 1998; Kijko, 2004), described in Appendix B. The activity rate (λ_A) is the expected number of earthquakes of a given magnitude and stronger that will occur per unit time (e.g. per year). The Gutenberg – Richter b-value gives the slope of the frequency–magnitude curve and defines the ratio between the number of large and small earthquake occurrences. The maximum possible regional characteristic earthquake magnitude ($m_{\max}$), is the upper limit of magnitude for a given seismogenic source zone or entire region. The characteristic seismic hazard is expressed in terms of the probability of occurrence of an earthquake of a particular magnitude and its associated mean return period.

2.1. Karachi Area

2.1.1. The Area-Specific Hazard Parameters

The calculations are based on a catalogue spanning approximately 570 years (Appendix D), we obtained a maximum credible earthquake magnitude, $\hat{m}_{\max}$ = 8.44 ± 0.29, the Gutenberg-Richter parameter $\hat{b}$ = 0.90 ± 0.07, and a mean area-characteristic seismic activity rate, $\hat{\lambda}_A$ = 2.52 ± 0.46 per year (for $m_{\min}$ = 5.0).

2.1.2. Earthquake Magnitude Exceedance Probabilities and Mean Return Periods

The input parameters and the results of the PSHA are given in Appendix D. The range of expected magnitudes is specified from 5 to 8.4. For each magnitude, the calculated activity rate, return period, and probabilities of exceedance in 1, 50, 100 and 1 000 years are listed (Appendix D). For instance, a magnitude 6.0 earthquake is expected to occur once every 2.85 years in the area.

2.1.3. Plots of Earthquake Magnitude Exceedance Probabilities and Mean Return Periods

Figure 1 shows the probability for a given magnitude to be exceeded in one year. As an example, the probability for a magnitude equal to or greater than 6.0 to occur in one year is approximately 0.29 (29 %).

Figure 2 shows the mean return period of earthquakes with magnitudes in the range 5 to 8.4 units. Thus one can expect a magnitude 8 event to occur approximately every 162 years.

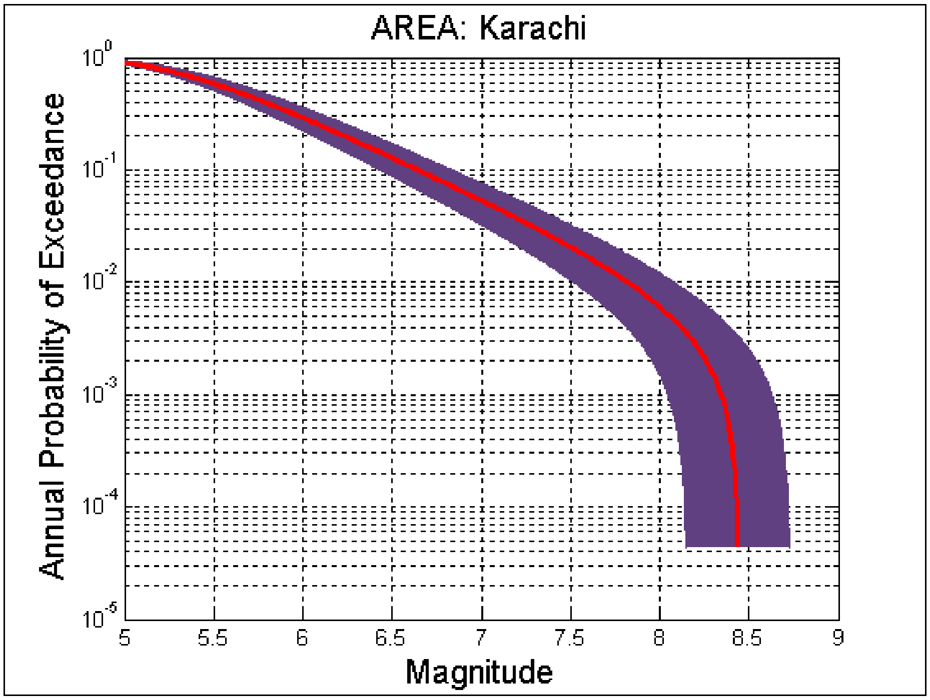

Figure 1. The annual probability of exceeding the specified magnitude. The red curve shows the mean probability, while the two blue curves indicate the mean probability plus and minus the standard deviation.

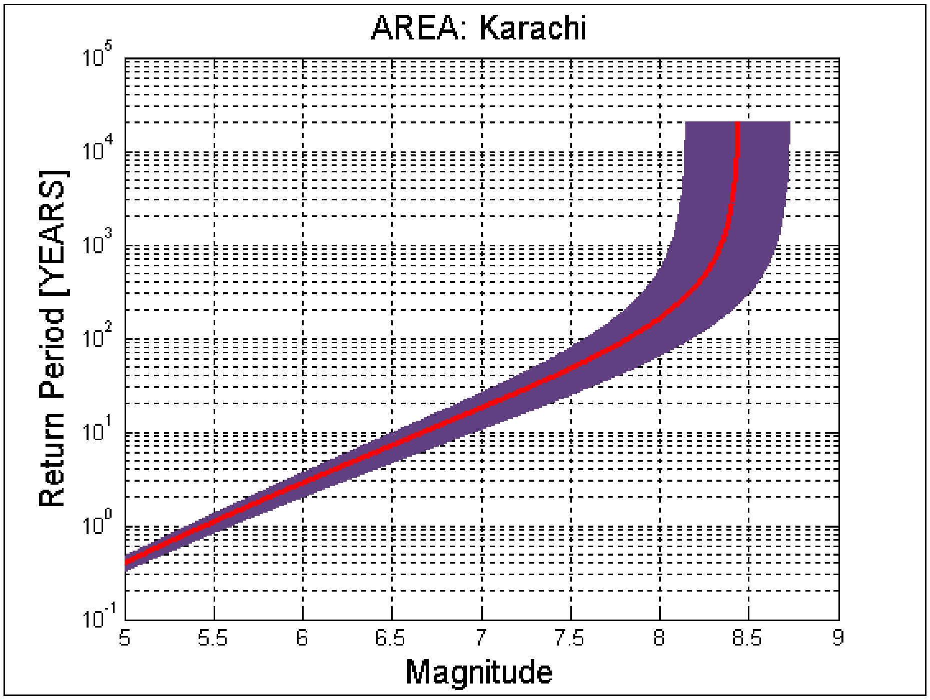

Figure 2. The mean return periods for earthquakes of magnitude 5 to 8.4 units .The red curve shows the mean return period, while the two blue curves indicate the mean return periods plus and minus the standard deviation.

2.2. South Sandwich Area

2.2.1. The Area-Specific Hazard Parameters

The calculations are based on a catalogue spanning approximately 32 years (Appendix E). We obtained for the area, a maximum credible earthquake magnitude, $\hat{m}_{\max}$ = 7.64 ± 0.24, the Gutenberg-Richter parameter $\hat{b}$ = 1.07 ± 0.09, and a mean area-characteristic seismic activity rate for the area $\hat{\lambda}_A$ = 8.42 ± 2.14 per year (for $m_{\min}$ = 5.5).

2.2.2. Earthquake Magnitude Exceedance Probabilities and Mean Return Periods

The input parameters and results of the PSHA are given in Appendix E. The range of expected magnitudes is specified from 5.5 to 7.6. For each magnitude the calculated activity rate, return period, and probabilities of exceedance in 1, 50, 100 and 1 000 years are listed in Appendix E. For instance, a magnitude 6.5 earthquake is expected to occur once every 1.3 years in the area.

2.2.3. Plots of Earthquake Magnitude Exceedance Probabilities and Mean Return Periods

Figure 3 shows the probability for a given magnitude to be exceeded in one year. As an example, the probability for a magnitude equal to or greater than 6.5 to occur in one year is approximately 0.53 (53 %).

Figure 4 shows the mean return period of earthquakes with magnitudes in the range 5.5 to 7.6 units. For instance, one can expect a magnitude 7 event to reoccur approximately every 4.64 years.

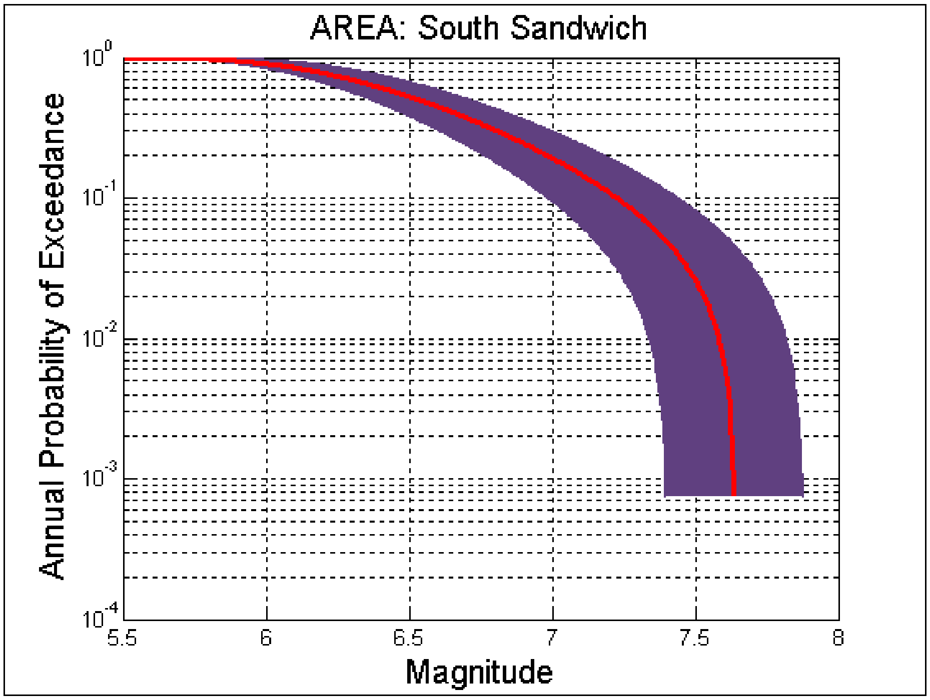

Figure 3. The annual probability of exceeding the specified magnitude. The red curve shows the mean probability, while the two blue curves indicate the mean probability plus and minus the standard deviation.

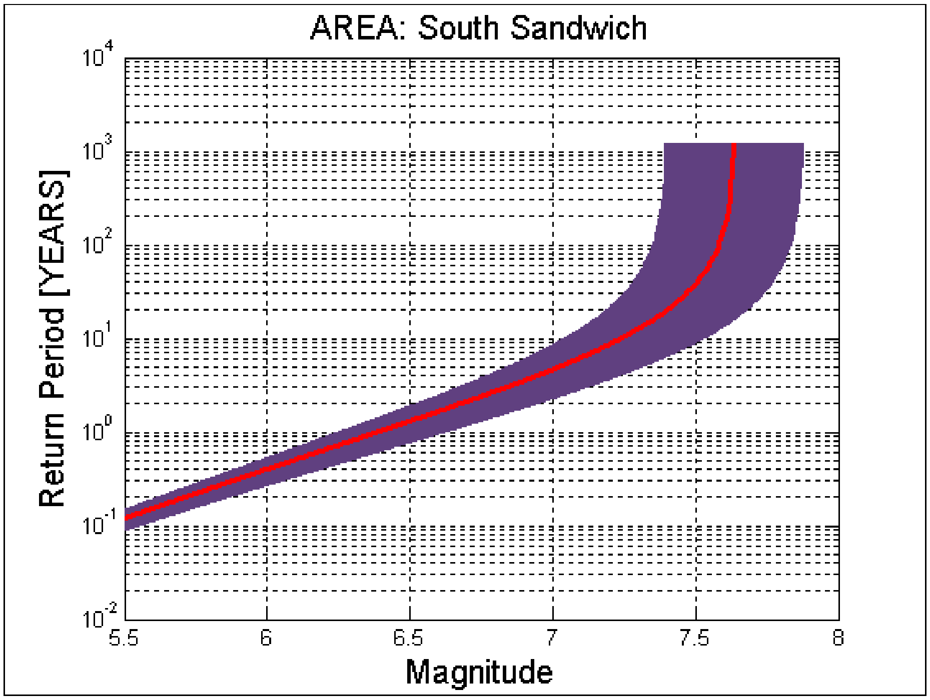

Figure 4. The mean return periods for earthquakes of magnitude 5.5 to 7.6 units .The red curve shows the mean return period, while the two blue curves indicate the mean return periods plus and minus the standard deviation.

2.3. Sumatra Area

2.3.1. The Area-Specific Hazard Parameters

Based on a catalogue spanning approximately 32 years (Appendix F), we obtain for the area, a maximum credible earthquake magnitude, $\hat{m}_{\max}$ = 9.20, the Gutenberg-Richter parameter $\hat{b}$ = 1.03 ± 0.09, and a mean area-characteristic seismic activity rate, $\hat{\lambda}_A = 9.18 \pm 2.12$ per year (for $m_{\min}$ = 5.5).

2.3.2. Earthquake Magnitude Exceedance Probabilities and Mean Return Periods

The input parameters and the results of the PSHA are given in Appendix F. The range of expected magnitudes is specified from 5.5 to 9.2. For each magnitude, the calculated activity rate, return period, and probabilities of exceedance in 1, 50, 100 and 1 000 years are listed in Appendix F. For instance, a magnitude 7.0 earthquake is expected to occur once every 2.73 years.

2.3.3. Plots of Earthquake Magnitude Exceedance Probabilities and Mean Return Periods

Figure 5 shows the probability for a given magnitude to be exceeded in one year. As an example, the probability for a magnitude equal to or greater than 7.0 to occur in one year is approximately 0.3 (30 %).

Figure 6 shows the mean return period of earthquakes with magnitudes in the range 5.5 to 9.2 units. For instance, one can expect a magnitude 8 event to occur after approximately every 19.3 years.

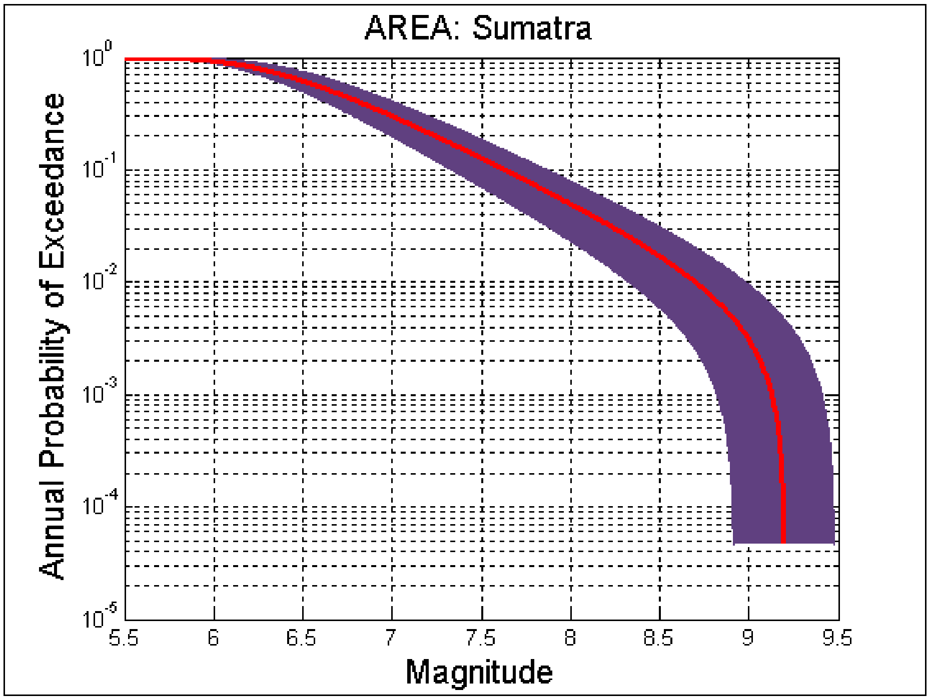

Figure 5. The annual probability of exceeding the specified magnitude . The red curve shows the mean probability, while the two blue curves indicate the mean probability plus and minus the standard deviation.

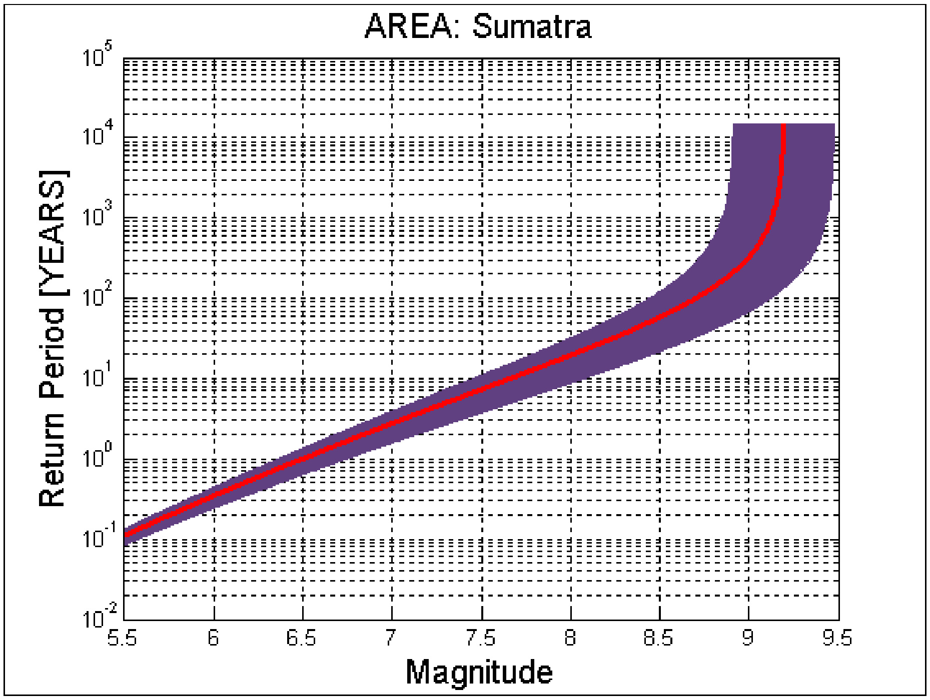

Figure 6. The mean return periods for earthquakes of magnitude 5,5 to 9,2 units .The red curve shows the mean return 33period, while the two blue curves indicate the mean return periods plus and minus the standard deviation.

3. Surface Fault Displacement

Relations used for the mean displacement, fault length and fault width (Table 1) were obtained from Papazachos *et al.,* (2004), which were determined for dip-slip faults from regions of lithospheric subduction. These were selected because regions (Karachi, South Sandwich and Sumatra) under discussion fall in regions of subduction. The relations are valid for a magnitude range of $6.7 \leq M \leq 9.2$.

Table 1: Moment magnitude and corresponding fault parameters obtained using equations 1, 2 and 3.

Region	**M_{max}**	**Mean Displacement (m)**	**Fault Length (km)**	**Fault Width (km)**	**Location**
Karachi	8.44	4.18	283.1	96.92	24.5^0N 63.0^0E
South Sandwich	7.64	1.29	102.8	54.75	55.1^0S 27.3^0W
Sumatra	9.20	12.82	741.3	166.72	03.3^0N 95.8^0E

Since we are considering worst case scenarios, the largest expected magnitude values (M_{max}), as estimated in this report, were used for all the areas.

$$\text{Log}(u) = 0.64M - 2.78 \qquad (1)$$

Where u is the mean displacement and M is moment magnitude.

$$\text{Log}(L) = 0.55M - 2.19 \qquad (2)$$

Where L is the fault length and M is moment magnitude.

$$\text{Log}\ (w) = 0.31M - 0.63 \qquad (3)$$

Where w is the fault width and M is the moment magnitude.

Table 2. Fault plane parameters for Sumatra (McCloskey *et al.*, 2008; Singh, 2006), Karachi (Engdahl and Villasenor, 2002; Byrne *et al.*, 1992) and South Sandwich (USGS, 2006) subduction regions

Region	**Dip angle** (degrees)	**Depth** (km)
Karachi	7 (2 – 27)	25 - 27
South Sandwich	50	<50
Sumatra	8 - 15	25 - 30

The dip angles and fault plane depths given in Table 2 are based on available information on past tsunami – generating earthquakes as well as from projects to predict future tsunamis (e.g. McCloskey *et al.*, 2008).

4. Conclusion

The information used in determining the relations used to calculate mean displacement, fault length and fault width was obtained from aftershock distribution and fault modelling. Therefore, there are no direct measurements of fault displacement. It is beyond the scope of this work to give actual locations of predicted earthquake origins as the earthquakes can occur anywhere along the plate boundaries in the areas discussed. Thus we gave locations of either the northernmost point of the boundary or previous location of a large earthquake that caused a tsunami (Sumatra region). It is also recommended that different strike angles be used in the tsunami wave modelling to determine the fault strike that produces the worst case in combination with other parameters.

It is important to note that not all earthquakes of quoted magnitudes in the areas discussed generate tsunamis. Rather, only a small fraction of them do. Thus, the calculated activity rates need to be corrected by multiplying by the fraction, estimated to be approximately 1%. Certainly more investigations are required to determine a realistic fraction. Therefore, this study should be treated as a very preliminary one.

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Appendix A:

Outline of the Parametric-Historic Procedure for Probabilistic Seismic Hazard Assessment

The aim of this outline is to provide the reader with key elements of the Parametric-Historic probabilistic seismic hazard analysis procedure. In addition, in all calculations, uncertainty of the employed seismicity models has been incorporated, by incorporation of the Bayesian formalism.

The objective of seismic hazard assessment is to obtain long-term probabilities of the occurrence of seismic events of a specified size in a given time interval.

In this report, the seismic hazard was assessed in terms of PGA using the Parametric-Historic procedure described in Kijko and Graham (1998, 1999). Seismic hazard analysis was done on the basis of the whole seismological record available for area, including historical observations as well as the instrumental data recorded during the past decades, covering a period of almost two millennia. The maximum possible PGA value for the site was obtained by applying the (floating) earthquake procedure, assuming the occurrence of the strongest possible earthquake at very close distance from the site. The probabilities of exceedance of the maximum possible PGA values were also calculated to illustrate the uncertainty of maximum PGA estimation.

The method used to estimate the level of seismic hazard in terms of PGA has been described in detail in Kijko and Graham (1998, 1999), and Kijko (2004).

The statistical techniques that can be used for the evaluation of the maximum regional earthquake magnitude, $m_{\max}$ is described in papers Kijko and Graham (1998) and Kijko (2004). The work by Kijko and Graham (1999) delineates a methodology for probabilistic seismic hazard assessment at a given site.

Site-specific analyses of seismic hazard require a knowledge of the attenuation of the selected ground-motion parameter a, usually PGA, as a function of distance. According to the adopted methodology, the attenuation law of PGA is assumed to be of the type,

$$\ln(a) = c_1 + c_2 \cdot m + \phi(r) + \varepsilon, \tag{1}$$

where c_1 and c_2 denote empirical coefficients, m is the earthquake magnitude, $\phi(r)$ is a function of earthquake distance and ε is a normally distributed random error.

To express seismic hazard in terms of PGA, the aim would be to calculate the conditional probability that an earthquake of random magnitude, occurring at a random distance from the site, will cause a PGA value equal to, or greater than, the chosen threshold value, $a_{\min}$, at the site. We accept the standard assumption (e.g., Page, 1968) that the random earthquake magnitude, m, in the range of $m_{\min} \leq m \leq m_{\max}$, is distributed according to the doubly truncated Gutenberg-Richter relation

$$\log N(m) = a - b \cdot m, \tag{2}$$

where $N(m)$ is the number of earthquakes with magnitude m, and stronger, and a and b are parameters. (See Figure 1).

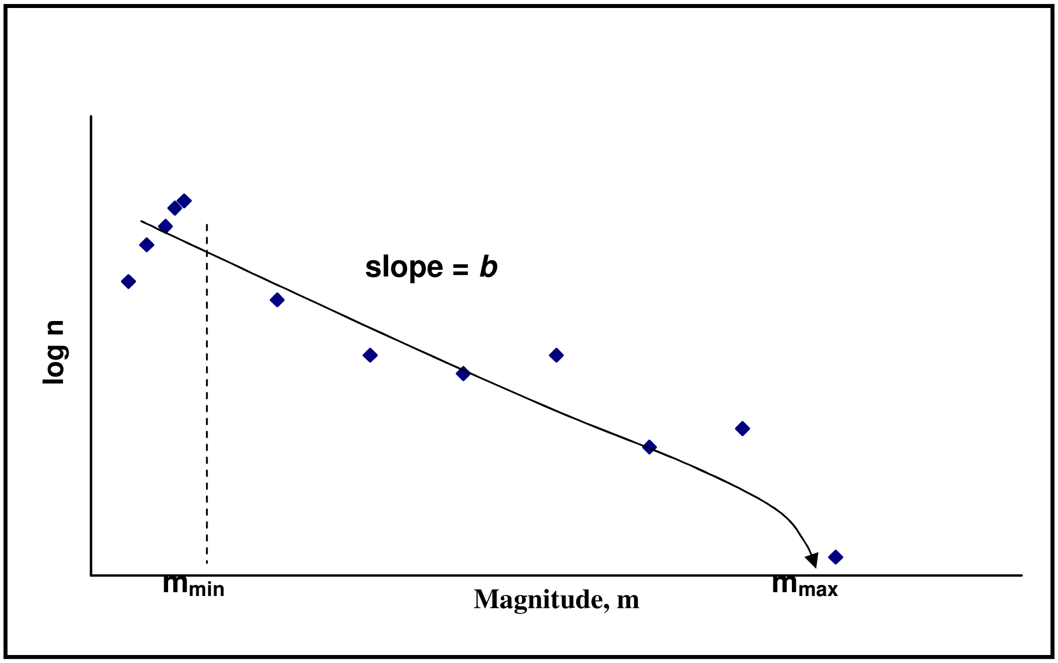

Figure 1. Schematic illustration of the doubly truncated frequency-magnitude Gutenberg-Richter relation. The slope of the curve is described by parameter b, known as b-value of the Gutenber-Richter. Value m_{min} is the minimum earthquake magnitude corresponding to acceleration a_{min}, which is the minimum value of PGA of engineering interest and m_{max} is the regional characteristic, maximum credible earthquake magnitude.

Acceptance of the classical frequency-magnitude Gutenberg-Richter relation (2) is equivalent to the assumption that the cumulative distribution function (CDF) of earthquake magnitude is of the form

$$F_M(m) = \frac{\exp(-\beta m_{\min}) - \exp(-\beta m)}{\exp(-\beta m_{\min}) - \exp(-\beta m_{\max})}. \tag{3}$$

In Figure B1 and equation (3), $m_{\min}$ is the minimum earthquake magnitude corresponding to acceleration $a_{\min}$, which is the minimum value of PGA of engineering interest at the site, m_{max} is the maximum credible (maximum possible) earthquake magnitude and $\beta = b$ ln10, where b is the parameter of the Gutenberg-Richter magnitude-frequency relation (2).

It can be shown (Kijko and Graham, 1999) that choosing equation (1) as a model for attenuation of PGA and equation (2) as a distribution of earthquake magnitude, is equivalent to the assumption that

$$\log N(x) = c - d \cdot x, \tag{4}$$

where $N(x)$ is the number of earthquakes recorded at the site, with PGA, a, equal to or exceeding $x = \ln(a)$, c and d are parameters and $d=b/c_2$, where c_2 is the coefficient related to the attenuation formula (1). Equation (4) schematically is illustrated in Figure B2.

From equation (4) it follows that CDF of the logarithm of PGA a, denoted as x, is of the form,

$$F_X(x) = \frac{\exp(-\gamma x_{\min}) - \exp(-\gamma x)}{\exp(-\gamma x_{\min}) - \exp(-\gamma x_{\max})}, \tag{5}$$

where, $x_{\min} = \ln(a_{\min})$, $x_{\max} = \ln(a_{\max})$, $a_{\max}$ is the maximum possible PGA at the site, $\gamma = \beta/c_2$ and β is the parameter of the Gutenberg Richter distribution of earthquake magnitude. It can be seen from formula (5) that the logarithm of the PGA at a given site follows the same type of distribution as the earthquake magnitude, i.e. doubly truncated negative exponential – the form of the Gutenberg-Richter distribution. The two distributions differ only in the value of their parameters. If the parameter of the magnitude distribution is equal to β, the parameter of the distribution of x = ln(PGA) is equal to β/c_2.

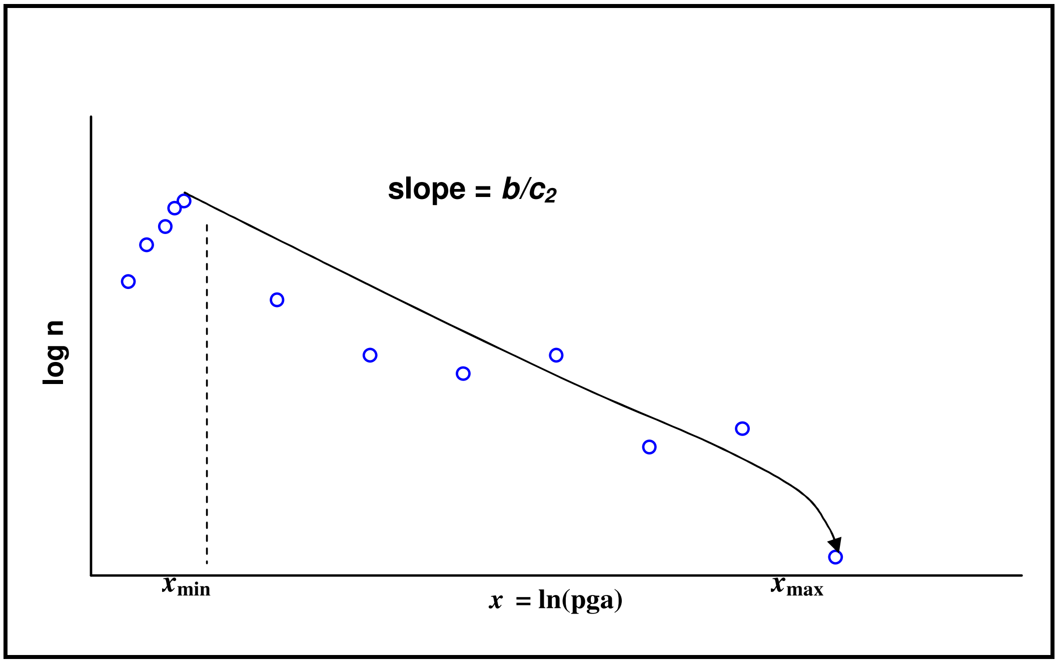

Figure 2 Schematic illustration of the distribution of the PGA. If earthquake magnitude follow a doubly truncated Gutenberg-Richter relation, the logarithm of the PGA at a given site follows the same type of distribution as the earthquake magnitude (2), i.e. doubly truncated negative exponential – the form of the Gutenberg-Richter distribution in equation (2). The two distributions differ only in the value of their parameters. If the parameter of the magnitude distribution is equal to b, the parameter of the distribution of x = ln(PGA) is equal to b/c2.

One should note that CDF (3) was derived under the condition that the no matter how diverse the spatial distribution of seismicity within the area surrounding the specified site is, the earthquake magnitude distribution described by parameters $m_{\max}$ and β remain the same.

Probabilistic seismic hazard, $H(a)$, is defined as the probability of a given value of PGA a (equal to, or greater than, the chosen threshold value, $a_{\min}$) being exceeded at least once at the site during a specified time interval t. Such a probability can be written as

$$H(x \mid t) = 1 - \exp\{-\lambda_s t[1 - F_X(x)]\} \tag{6}$$

where λ is the site-specific activity rate of earthquakes that cause a PGA value, a, at the site, exceeding the threshold value $a_{\min}$. Clearly, a hazard curve so defined is doubly truncated: from below, by $x_{min} = \ln(a_{min})$, and from above, by $x_{max} = \ln(a_{max})$. The distribution in equation (4) was derived under the assumption that the earthquakes that cause a PGA value a, $a \geq a_{min}$, at the site, follow the Poisson process with mean activity rate $\lambda(x) = \lambda\,[1 - F_X\,(x)]$, with $x = \ln(a)$.

The maximum likelihood method is used to estimate the site-characteristic seismic hazard parameters λ and γ.

For a given value of $x_{\max}$ (or equivalently, the maximum possible PGA at the site), the maximum likelihood procedure leads to the determination of the parameters λ and γ. However, this procedure for the estimation of unknown hazard parameters is used only when the *b* parameter of the Gutenberg-Richter frequency-magnitude relationship is not known. When the *b* value is known, parameter γ is calculated as β/c_2 and the maximum likelihood search reduces to the estimation of the site-specific mean seismic activity rate λ.

REFERENCES TO PSHA METHODOLOGY OUTLINE

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Appendix B:

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K-S Hazard Area Methodology

Introduction

Following McGuire (1993), the existing procedures of probabilistic seismic hazard analysis (PSHA) fall into two main categories: deductive and historic. The Parametric-Historic Procedure is a combination of the deductive and historic procedures. Both these procedures along with their weak and strong points will be discussed first before introducing the Parametric-Historic Procedure.

The Deductive and Historic Procedures

The theoretical basis for the deductive method is provided by Cornell (1968). The approach permits the incorporation of geological and geophysical information to supplement the seismic event catalogues. Application of this procedure includes several steps. The initial step requires the definition of potential seismic sources, usually associated with geological or tectonic features (e.g. faults), and the delineation of potentially active regions (seismogenic source zones) over which all the available information is averaged. This is followed by determining the seismicity parameters for each seismogenic source zone. Use is made of the most common assumptions in engineering seismology that earthquake occurrences follow a Poisson process and that earthquake magnitudes follow a Gutenberg-Richter doubly-truncated distribution. Following this assumption the parameters obtained for each seismogenic source zone are: the mean seismic activity rate, λ (which is a parameter of the Poisson distribution), the level of completeness of the earthquake catalogue, $m_{\min}$, the maximum regional earthquake magnitude, $m_{\max}$, and the Gutenberg-Richter parameter, b. To assess the above parameters a seismic event catalogue containing origin times, size of seismic events and spatial locations is needed. With the selection of the ground-motion relation the distribution function for a required ground motion parameter can be calculated. The final step requires the integration of individual contributions from each seismogenic zone into a site-specific distribution.

Probably the strongest point of any deductive-type procedure of PSHA is its ability to account for all sorts of deviations from the "standard" model, i.e. it accounts for phenomena such as migration of seismicity, and seismic “gaps”. This is possible because the procedure is parametric by nature. Unfortunately, the deductive procedure also has significantly weak points. The major disadvantage stems from the requirement of specifying seismogenic source zones. Often tectonic provinces or specific active faults have not been identified and mapped and the causes of seismicity are not well understood. In addition, with the Cornell-based seismic hazard assessment procedure, knowledge of the model parameters is required for each zone and these cannot always be determined reliably for areas that are small or have incomplete seismic histories.

The second category of PSHA consists of the so-called historic methods (Veneziano et al., 1984), which, in their original form, are non-parametric. These methods require, as input data, information about past seismicity only, and do not require specification of seismogenic zones. Based on spatial and temporal distribution of seismicity, the empirical distribution of the required seismic hazard parameter is estimated. By normalizing this distribution for the duration of the seismic event catalogue, one obtains an annual rate of the exceedance of the required hazard parameter.

The major advantage of this method is that a specification of seismogenic source zones is not needed. Furthermore, the approach does not require designation of the model used. By its nature, the historic method works well in areas of frequent occurrence of strong seismic events, when the record of past (historic) seismicity is “reasonably” complete. At the same time, the non-parametric historic approach has significant weak points. Its primary disadvantage is a rather poor reliability in estimating small probabilities for areas of low seismicity. The procedure is not recommended for an area where the seismic event catalogues are incomplete. In addition, in its present form, the procedure is not capable of making use of any additional geophysical or geological information to supplement the pure seismological data.

A procedure that accepts the varying quality of different parts of the catalogue and at the same time does not require specification of seismic source zones would be an ideal tool for analyzing and assessing seismic hazard. Bearing in mind both the weak and strong points of the above two approaches, the authors have developed an alternative procedure (Kijko and Graham, 1998, 1999), which, following the scheme of McGuire, could be classified as a parametric-historic approach. The approach combines the best of the deductive and non-parametric historic procedures and, in many cases, is free from the basic disadvantages characteristic of each of these procedures.

The Parametric-Historic Procedure

The applied PSHA procedure consists of two steps. The first step is applicable to the area in the vicinity of the site, for which the seismic hazard assessment is required. This is followed by a site-specific hazard assessment based on a selected ground motion parameter. The assessment in terms of peak ground acceleration (PGA) and acceleration response spectra (ARS) is described.

The maximum regional magnitude, $m_{\max}$, is of paramount importance in this approach, therefore a statistical technique that can be used for evaluating this important parameter is presented.

Input Data

The lack or incompleteness of data in earthquake catalogues is a frequent issue in a statistical analysis of seismic hazard. Contributing factors include the historical and socio – economic context, demographic variations and alterations in the seismic network. Generally, the degree of completeness is a monotonically increasing function of time, i.e. the more recent portion of the catalogue has a lower level of completeness. The methodology makes provision for the earthquake catalogue to contain three types of data: firstly, very strong prehistoric seismic events (paleo-earthquakes), which usually occurred over the last thousands of years. Secondly, the macro-seismic observations of some of the strongest seismic events that occurred over a period of the last few hundred years, and finally, complete recent data for a relatively short period of time. The complete part of the catalogue can be divided into several sub-catalogues, each of which is complete for events above a given threshold magnitude $m_{\min}^{(i)}$, and occurring in a certain period of time T_i where $i = 1,\ldots,s$ and s is the number of complete sub-catalogues. The approach permits 'gaps' (T_g) when records were missing or the seismic networks were out of operation. Uncertainty in earthquake magnitude is also taken into account in that an assumption is made that the observed magnitude is true magnitude subjected to a random error that follows a Gaussian distribution having zero mean and a known standard deviation. Figure 1 depicts the typical scenario confronted when conducting seismic hazard assessments.

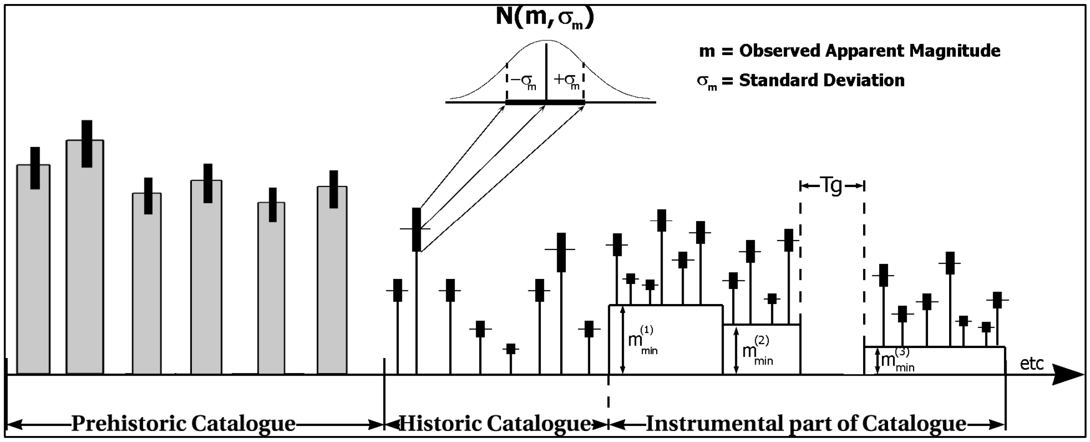

Figure 1 . Illustration of data which can be used by the seismic hazard assessment code developed at CGS.

Statistical Preliminaries

Basic statistical distributions and quantities utilised in the development of the methodology are briefly described in what follows.

The Poisson distribution is used to model the number of occurrences of a given earthquake magnitude or a given amplitude of a selected ground motion parameter being exceeded within a specified time interval.

$$p(n|\lambda,t) = P(N = n|\lambda,t) = \frac{(\lambda t)^n}{n!} e^{-\lambda t} \quad n=0,1,2,... \tag{1}$$

Note that λ here refers to the mean of the distribution, and describes the mean activity rate (mean number of occurrences).

The gamma distribution, given its flexibility, is used to model the distribution of various parameters in our approach and is given by,

$$f(x) = (x)^{q-1} \frac{p^q}{\Gamma(q)} e^{-px}, \qquad x > 0 \ , \tag{2}$$

where $\Gamma(q)$ is the gamma function defined as,

$$\Gamma(q) = \int_0^\infty y^{q-1}e^{-y}dy, \quad q > 0, \tag{3}$$

The parameters p and q are related to the mean μ, and variance σ^2, of the distribution according to,

$$\mu_x = \frac{q}{p}, \tag{4}$$

$$\sigma_x{}^2 = \frac{q}{p^2}, \tag{5}$$

The coefficient of variation expresses the uncertainty related to a given parameter, and is given by,

$$COV_x = \frac{\sigma_x}{\mu_x}, \tag{6}$$

thus describing the variation of a parameter relative to it's mean value, with a higher value indicating a greater dispersion of the parameter.

Estimation of the Area-Specific Hazard

The standard assumption adopted is that the distribution of earthquakes with respect to their size obeys the classical Gutenberg-Richter relation,

$$\log N(m) = a - b \cdot (m - m_{\min}), \tag{7}$$

where $N(m)$ is the number of earthquakes of $m \geq m_{\min}$, occurring within a specified period of time, and a and b are parameters.

Epstein and Lomnitz (1966) found that equation (7) implied a singly truncated exponential distribution of the form,

$$F_M(m) = P(M \le m) \\ = 1 - e^{-\beta(m - m_{\min})}, \tag{8}$$

where $\beta = b\ln(10)$.

The earthquake occurrences over time in the given area are assumed to satisfy a Poisson process (1) having an unknown mean seismic activity rate λ_A.

The disregard of temporal variations of the parameters λ_A and b can lead to biased estimates of seismic hazard. An explicit assumption behind most hazard assessment procedures is that parameters λ_A and b and remain constant in time. However, examination of most earthquake catalogues indicates that there are temporal changes of the mean seismic activity rate λ_A as well as of the parameter b. For some seismic areas, the b-value has been reported to change (decrease/increase) its value before large earthquakes. Usually, such changes are explained by the state of stress; the higher the stress, the lower the b-value. Other theories connect the b-value with the homogeneity of the rock: the more heterogeneous the rock, the higher the b-value. Finally, some scientists connect the fluctuation of the b-value with the seismicity pattern and believe that the b-value is controlled by the buckling of the stratum. Whatever the mechanism, the phenomenon of b-value fluctuation is indubitable and well-known. A wide range of international opinions concerning changes of patterns in seismicity, together with an extensive reference list, are found in a monograph by Simpson and Richards (1981) and in a special two issue of the Pure and Applied Geophysics, (Seismicity Patterns …, 1999; Microscopic and Macroscopic …, 2000). Treating both parameters λ_A and b as random variables modelled by respective gamma distributions allows us to appropriately account for the statistical uncertainty in these important parameters. In practice, the adoption of the gamma distribution does not really introduce much limitation, since the gamma distribution can fit a large variety of shapes. Combining the Poisson distribution (1) together with the gamma distribution (2) with parameters p_λ and q_λ, we obtain the probability related to a certain number of earthquakes, n, per unit time t, for randomly varying seismicity,

$$P(n|t) = \int_0^\infty p(n|\lambda_A, t) f(\lambda_A) d\lambda_A$$
$$= \frac{\Gamma(n+q_\lambda)}{n!\Gamma(q_\lambda)} \left(\frac{p_\lambda}{t+p_\lambda}\right)^{q_\lambda} \left(\frac{t}{t+p_\lambda}\right)^{n}, \tag{9}$$

where $p_\lambda = \bar{\lambda}_A / \sigma_\lambda^2$, $q_\lambda = \bar{\lambda}_A^2 / \sigma_\lambda^2$ and $\Gamma(\cdot)$ is the Gamma function (3). $\bar{\lambda}_A$ denotes the mean of the distribution of λ_A.

Similarly, combining the exponential distribution (8) with the gamma distribution for β with parameters p_β and q_β, and normalising (e.g. Campbell 1982) upon introducing an upper limit $m_{\max}$ for the distribution of earthquake magnitudes, we obtain the CDF of earthquake magnitudes,

$$F_M(m|m_{\min}) = C_\beta \left[1 - \left(\frac{p_\beta}{p_\beta + m - m_{\min}}\right)^{q_\beta}\right], \tag{10}$$

where $p_\beta = \bar{\beta} / \sigma_\beta^2$ and $q_\beta = \bar{\beta}^2 / \sigma_\beta^2$. The symbol $\bar{\beta}$ denotes the mean value of parameter β, σ_β denotes the standard deviation of β and the normalizing coefficient C_β is given by,

$$C_\beta = \left[1 - \left(\frac{p_\beta}{p_\beta + m - m_{\min}}\right)^{q_\beta}\right]^{-1}, \tag{11}$$

Noting that $q_\lambda = \bar{\lambda}_A \cdot p_\lambda$ and $q_\beta = \bar{\beta} \cdot p_\beta$, equations (9) and (10) may alternatively be written respectively as,

$$P(n|t) = \frac{\Gamma(n+q_\lambda)}{n!\Gamma(q_\lambda)} \left(\frac{q_\lambda}{\bar{\lambda}_A t + q_\lambda}\right)^{q_\lambda} \left(\frac{\bar{\lambda}_A t}{\bar{\lambda}_A t + q_\lambda}\right)^{n}, \tag{12}$$

and

$$F_M\left(m\middle|m_{\min}\right)=C_\beta\left[1-\left(\frac{q_\beta}{q_\beta+\beta\left(m-m_{\min}\right)}\right)^{q_\beta}\right], \tag{13}$$

with

$$C_\beta=\left[1-\left(\frac{q_\beta}{q_\beta+\beta\left(m_{\max}-m_{\min}\right)}\right)^{q_\beta}\right]^{-1}, \tag{14}$$

Note that $q_\beta = \left(COV_\beta^{\ -1}\right)^2$ and $q_\lambda = \left(COV_\lambda^{\ -1}\right)^2$. Upon specification of the COV, the parameters $\overline{\lambda}_A$ and $\overline{\beta}$, referred to as hyper-parameters of the respective distributions are estimated on the basis of observed data by applying the maximum likelihood procedure.

Extreme Magnitude Distribution as Applied to Prehistoric (Paleo) and Historic Events

Let us build the likelihood function of desired seismicity parameters $\boldsymbol{\theta} = (\overline{\lambda}_A, \overline{\beta})$, based on the prehistoric (paleo) and historic parts of the catalogue, containing the strongest events only. In this section we will only discuss the details of the likelihood function based on historic earthquakes, since except for a few details, the likelihood function based on prehistoric events is built in a similar manner.

By the Theorem of the Total Probability (see e.g. Cramér, 1961), the probability that in time interval t either no earthquake occurs, or all occurring earthquakes have magnitude not exceeding m, may be expressed as (Epstein and Lomnitz, 1966; Gan and Tung, 1983; Gibowicz and Kijko, 1994)

$$F_M^{\max}\left(m\,|\,m_0\,,t\right)=\sum_{i=0}^{\infty}P\left(i\middle|t\right)\left[F_M\left(m\,|\,m_0\right)\right]^i, \tag{15}$$

Relation (15) can be expressed in a much more simpler form (e.g. Campbell, 1982), which, in our notation, may be written as

$$F_M^{\max}\left(m \middle| m_0, t\right)=\left[\frac{q_\lambda}{q_\lambda+\bar{\lambda}_0\, t\left[1-F_M\left(m \middle| m_0\right)\right]}\right]^{q_\lambda}, \tag{16}$$

In relations (15) and (16), m_0 is the threshold magnitude for the prehistoric or historic part of the catalogue ($m_0 \geq m_{\min}$). Magnitude $m_{\min}$ plays the role of the 'total' threshold magnitude and has a rather formal character. The only restriction on the choice of its value is that $m_{\min}$ may not exceed the threshold magnitude of any part, prehistoric, historic or complete, of the catalogue.

It follows from relation (16) that the probability density function (PDF) of the largest earthquake magnitudes m within a period t is,

$$f_M^{\max}(m \mid m_0, t)=\frac{\bar{\lambda}_0\, t q_\lambda f_M(m \mid m_0) F_M^{\max}(m \mid m_0, t)}{q_\lambda+\bar{\lambda}_0\, t[1-F_M(m \mid m_0)]}\ , \tag{17}$$

$\bar{\lambda}_0$ represents the mean of the distribution of the mean activity rate for earthquakes with magnitudes not less than m_0 , and is given by,

$$\bar{\lambda}_0=\bar{\lambda}_A\left[1-F_M\left(m \middle| m_0\right)\right], \tag{18}$$

where $\bar{\lambda}_A$, as defined above, is mean of the distribution of the mean activity rate corresponding to magnitude value $m_{\min}$. $f_M\left(m \middle| m_0\right)$ is the PDF of earthquake magnitudes. Based on (13) and the definition of the probability density function, it takes the following form:

$$f_M(m)=C_\beta\, \bar{\beta}\left(\frac{q_\beta}{q_\beta+\bar{\beta}\left(m-m_0\right)}\right)^{q_\beta+1}, \tag{19}$$

After introducing the PDF (17) of the largest earthquake magnitude m within a period t, the likelihood function of unknown parameters $\boldsymbol{\theta}$, becomes:

$$L_0\left(\boldsymbol{\theta} \middle| \boldsymbol{m}_0, \boldsymbol{t}_0, \boldsymbol{cov}\right)=\prod_{i=1}^{n_0} f_M^{\max}\left(m_{0i} \middle| m_0, t_i\right), \tag{20}$$

In order to build the likelihood function (20), three kinds of input data are required: $\boldsymbol{m}_0$, $\boldsymbol{t}$, and $\boldsymbol{cov}$, where $\boldsymbol{m}_0$ is vector of the largest magnitudes, $\boldsymbol{t}$ denotes vector of the time intervals within which the largest events occurred and vector $\boldsymbol{cov} = (\mathrm{cov}_\lambda, \mathrm{cov}_\beta)$, consists of the coefficients of variation (amount of dispersion (/ uncertainty) relative to the mean) of the unknown parameters $\boldsymbol{\theta} = (\overline{\lambda}_A, \overline{\beta})$.

Combination of Extreme and Complete Seismic Catalogues with Different Levels of Completeness

Let us assume that the third, complete part of the catalogue, can be divided into s sub-catalogues (Figure 1). Each of them has a span T_i and is complete starting from the known magnitude $m_{\min}^{(i)}$. For each sub-catalogue i, $\boldsymbol{m}_i$ is used to denote n_i earthquake magnitudes m_{ij}, where $m_{ij} \geq m_{\min}^{(i)}$, $i = 1,\ldots,s$, and $j = 1,\ldots,n_i$. Let $L_i(\boldsymbol{\theta}|\boldsymbol{m}_i)$ denote the likelihood function of the unknown $\boldsymbol{\theta} = (\overline{\lambda}_A, \overline{\beta})$, based on the i-th complete sub-catalogue. If the size of seismic events is independent of their number, the likelihood function $L_i(\boldsymbol{\theta}|\boldsymbol{m}_i)$ is the product of two functions, $L_i(\overline{\lambda}_A|\boldsymbol{m}_i)$ and $L_i(\overline{\beta}|\boldsymbol{m}_i)$.

The assumption that the number of earthquakes per unit time is distributed according to (12), means that $L_i(\overline{\lambda}_A|\boldsymbol{m}_i)$ has the following form:

$$L_i(\overline{\lambda}_A|\boldsymbol{m}_i) = const \cdot \left(\overline{\lambda}_A^{(i)} t + q_\lambda\right)^{-q_\lambda} \left(\frac{\overline{\lambda}_A^{(i)} t}{\overline{\lambda}_A^{(i)} t + q_\lambda}\right)^{n_i}, \tag{21}$$

where $const$ does not depend on $\overline{\lambda}_A$ and $\overline{\lambda}_A^{(i)}$ is the mean activity rate corresponding to the threshold magnitude $m_{\min}^{(i)}$ and is given by,

$$\overline{\lambda}_A^i = \overline{\lambda}_A \left[1 - F_M\left(m_{\min}^{(i)} \mid m_{\min}\right)\right], \tag{22}$$

Following the definition of the likelihood function based on a set of independent observations, and (19), $L_i(\overline{\beta}|\boldsymbol{m}_i)$ takes the form,

$$L_i\left(\overline{\beta}\middle|\boldsymbol{m}_i\right)=\left[C_\beta\,\overline{\beta}\right]^{n_i}\prod_{j=1}^{n_i}\left[1+\frac{\overline{\beta}}{q_\beta}\left(m_{ij}-m_{\min}^{(i)}\right)\right]^{-\left(q_\beta+1\right)}, \qquad (23)$$

Relations (21) and (23) define the likelihood function of the unknown parameters $\boldsymbol{\theta}=(\overline{\lambda}_A,\overline{\beta})$ for each complete sub-catalogue.

Finally, $L(\boldsymbol{\theta})$, the joint likelihood function based on all data, i.e. the likelihood function based on the whole catalogue, is calculated as the product of the likelihood functions based on prehistoric, historic and complete data.

The maximum-likelihood estimates of the required hazard parameters $\boldsymbol{\theta}=(\overline{\lambda}_A,\overline{\beta})$, are given by the value of $\boldsymbol{\theta}$ which, for a given maximum regional magnitude $m_{\max}$, maximizes the likelihood function $L(\boldsymbol{\theta})$. The maximum of the likelihood function is obtained by solving the system of two equations $\frac{\partial \ell}{\partial \overline{\lambda}_A}=0$ and $\frac{\partial \ell}{\partial \overline{\beta}}=0$, where $\ell=\ln[L(\boldsymbol{\theta})]$.

A variance-covariance matrix, $D(\boldsymbol{\theta})$, of the estimated hazard parameters, $\hat{\overline{\lambda}}_A$ and $\hat{\overline{\beta}}$, is calculated according to the formula (Edwards, 1972):

$$\mathrm{D}(\theta)=-\begin{bmatrix}\frac{\partial^2\ell}{\partial\overline{\lambda}_A{}^2} & \frac{\partial^2\ell}{\partial\overline{\lambda}_A\partial\overline{\beta}}\\ \frac{\partial^2\ell}{\partial\overline{\beta}\partial\overline{\lambda}_A} & \frac{\partial^2\ell}{\partial\overline{\beta}^2}\end{bmatrix}^{-1}, \qquad (24)$$

where derivatives are calculated at the point $\overline{\lambda}_A=\hat{\overline{\lambda}}_A$ and $\overline{\beta}=\hat{\overline{\beta}}$.

Estimation of the Maximum Regional Earthquake Magnitude $m_{\max}$

Suppose that in the area of concern, within a specified time interval T, there are n main seismic events with magnitudes $m_1,\ldots,m_n$. Each magnitude $m_i \geq m_{\min}$ ($i=1,\ldots,n$), where $m_{\min}$ is a known threshold of completeness (i.e. all events having magnitude greater than or equal to $m_{\min}$ are recorded). It is further assumed that the seismic event magnitudes are independent, identically distributed, random variables with CDF described by equation (13).

From the condition that compares the largest observed magnitude $m_{\max}^{obs}$ and the maximum expected magnitude during a specified time interval T, we obtain the maximum regional magnitude $m_{\max}$ (Kijko and Graham, 1998; Kijko, 2004)

$$m_{\max} = m_{\max}^{obs} + \frac{\delta^{1/q} \exp\left[nr^q / \left(1 - r^q\right)\right]}{\bar{\beta}} \left[\Gamma\left(-1/q, \delta r^q\right) - \Gamma\left(-1/q, \delta\right)\right], \tag{25}$$

where $\delta = nC_\beta$ and $\Gamma(\cdot,\cdot)$ is the complementary incomplete gamma function. The approximate variance of the above estimator is equal to (Kijko, 2004)

$$\sigma_{m_{\max}}^2 \cong \sigma_M^2 + \left\{ \frac{\delta^{1/q} \exp\left[nr^q / \left(1 - r^q\right)\right]}{\bar{\beta}} \left[\Gamma\left(-1/q, \delta r^q\right) - \Gamma\left(-1/q, \delta\right)\right] \right\}^2, \tag{26}$$

where σ_M is the standard error in determination of the largest observed magnitude $m_{\max}^{obs}$.

References

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Appendix C: Area-Specific Hazard Information File: Calcutta Area

```
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 File       : Calcutta_ha2_160408.doc
 Created on : 16-Apr-2008 10:49:19
=====================================================================

 SEISMIC HAZARD ASSESSMENT FOR SELECTED AREA
 FROM PRE-HISTORIC, HISTORIC, and INCOMPLETE DATA
 ORIGIN TIME OF PRE-HISTORIC EVENTS CAN BE UNCERTAIN

 FLOW OF SEISMIC EVENTS IS MODELED BY BAYESIAN-BASED EQUATIONS
 WHICH ACCOUNT UNCERTAINTY OF SEISMIC HAZARD MODEL

 HAZARD PARAMETERS BEATA AND LAMBDA ARE CALCULATED SIMULTANEOUSLY
 MAGNITUDE ERRORS ARE DISTRIBUTED NORMALLY
 RANGE OF MAGNITUDE INTEGRATION : < m_min, m_max >

 REGONAL MAXIMUM MAGNITUDE CAN BE ESTIMATED ACCORDING TO :

     (1) Gibowicz-Kijko (1994)
     (2) Gibowicz-Kijko-Bayes
     (3) Kijko-Sellevoll (1989)
     (4) Kijko-Sellevoll-Bayes
     (5) Tate-Pisarenko
     (6) Tate-Pisarenko-Bayes
     (7) Non-Parametric (Gaussian) procedure

 Theory of the HAZARD evaluation procedure is given in:

    "Estimation of earthquake hazard parameters
     from Incomplete data files", Part II.
     by A. Kijko and M.A. Sellevoll (1992)
     Bull. Seism. Soc. Am. vol.82, p.120-134.

  and

    "Parametric-Historic" procedure for probabilistic
     seismic hazard analysis. Part I. Assessment
     of maximum regional magnitude m_max.
     by A. Kijko and G. Graham (1998),
     Pure App. Geophys, vol. 152, p.413-442.

=====================================================================
 PROGRAM NAME     : HA2 (H = Hazard; A = Area)
 WRITTEN          : 15 AUG 1999 by A.Kijko
 REVISION 1       : 21 MAR 2005 by A.Kijko
 REVISION 2       : 25 JUL 2005 by J.Ramperthap
 REVISION 3       : 15 AUG 2005 by J.Ramperthap
 REVISION 4       : 22 JUN 2006 by A.Kijko
 VERSION          : 2.05
=====================================================================

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            jasonr@geoscience.org.za

=====================================================================

 NAME OF THE AREA: Calcutta


                        HISTORIC DATA:
                     ********************

 NAME OF HISTORIC DATA FILE: e

 BEGINING OF HISTORIC DATA (Y-M-D) = 1755 1 1
 END      OF HISTORIC DATA (Y-M-D) = 2005 1 18
 NUMBER OF HISTORIC EQ-s           = 103
 "THRESHOLD" MAG. OF HISTORIC EQ-s = 5
```

```
STANDARD ERROR OF EQ-e MAGNITUDE  = 0.25

1764   6   4  6.0
1816   5  26  8.0
1826  10  29  6.0
1833   8  26  8.0
1843   4  11  5.0
1846   5  27  6.5
1866   5  23  7.0
1868   6  30  7.5
1870   4  11  6.7
1897   6  12  8.5
1901   2  15  6.0
1906   8  31  7.0
1908  12  12  8.2
1909   2  17  5.0
1911  12   7  5.0
1912   5  23  8.0
1916   8  28  7.5
1917   4  12  6.0
1918   7   8  7.6
1920   8  15  6.0
1923   9   9  7.1
1924   1  30  6.0
1925  11   6  6.0
1926   5  10  6.2
1927   3  15  6.5
1928   7   9  6.0
1929   3  25  6.0
1930  12   3  7.3
1931   1  27  7.6
1932   3  24  6.0
1933   3   6  5.8
1934   1  15  8.2
1935   3  21  6.3
1936   5  10  6.0
1937   3   9  6.0
1938   1  29  6.0
1939   5  27  6.7
1940   2  13  6.0
1941   1  21  6.7
1942   8  19  6.0
1943  10  23  7.2
1944  12  24  6.0
1945   5  19  6.0
1946   9  12  7.5
1947   7  29  7.7
1948   6  27  6.3
1949  12  10  6.0
1950   8  15  8.5
1951   4   7  6.8
1952   1  15  6.0
1953   2  23  6.0
1954   3  21  7.2
1955   5   4  6.0
1956   7  16  7.0
1957   7   1  7.2
1958   3  22  6.5
1959   2  14  6.0
1960   7  29  6.5
1961   9  29  6.0
1962   9  22  6.2
1963   6  19  6.2
1964   7  12  6.7
1965   1  12  6.1
1966   6  27  6.1
1967   3  14  5.9
1968   5  31  5.7
1969   4  14  6.0
1970   7  29  6.5
1971   2   2  5.4
1972   8  21  5.1
1973   5  31  5.9
1974   3  24  5.7
1975   7   8  6.5
1976   5  29  7.0
1977   5  12  5.7
1979   1   1  5.3
1979  10   3  5.6
```

```
 1980   7  29  6.6
 1981   4  25  5.7
 1982   4   8  5.5
 1983   8  30  5.6
 1984   4  23  5.9
 1985   1   7  5.6
 1986   1  10  5.4
 1987   5  18  5.9
 1988   8   6  7.3
 1989   4  15  6.2
 1990   1   9  6.1
 1991   1   5  7.3
 1992   4  23  6.5
 1993   3  20  6.2
 1994   5  29  6.5
 1995   7  11  7.1
 1996  11  11  6.0
 1997  11  21  6.1
 1998   9   3  5.6
 1999   4   5  5.6
 2000   6   7  6.5
 2001   4  12  5.6
 2002  12   4  5.6
 2003   9  21  6.9
 2004  12  26  5.8
 2005   1  18  5.0

 LARGEST EQ IN HISTORIC CATALOG = 8.5


 PROVISION FOR INDUCED SEISMICITY : NOT REQUIRED
 ===============================================


                         ***

 TIME SPAN OF WHOLE CATALOG           = 250.04 [Y]
 MAXIMUM MAGNITUDE IN THE CATALOG     = 8.5
 SD OF MAXIMUM OBSERVED MAGNITUDE     = 0.25
 MODEL UNCERTAINTY OF BETA            = 25 [per cent]
 MODEL UNCERTAINTY OF LAMBDA          = 25 [per cent]

 CALCULATIONS ARE PERFORMED FOR MINIMUM MAGNITUDE Mmin = 5.00


 PRIOR VALUE OF PARAMETER b           = 1
 SD OF PRIOR b-VALUE                  = 0.1

                      RESULTS
                   *************

 BETA   = 1.98 +-  0.14 (b = 0.86 +- 0.06)
 LAMBDA = 4.301 +- 0.658 (for Mmin = 5.00)
 Mmax   = 8.71 +- 0.33  (for Mmax obs. = 8.50 +- 0.25)

 Maximum Regional Magnitude Mmax is calculated
 according to procedure by Kijko-Sellevoll-Bayes


Mag      Lambda          RP          Prob(T = 1  50   100   1000)

5.0   4.3007e+000   2.33e-001   0.97783   1.00000   1.00000   1.00000
5.1   3.5294e+000   2.83e-001   0.95880   1.00000   1.00000   1.00000
5.2   2.9031e+000   3.44e-001   0.93060   1.00000   1.00000   1.00000
5.3   2.3933e+000   4.18e-001   0.89251   1.00000   1.00000   1.00000
5.4   1.9772e+000   5.06e-001   0.84498   1.00000   1.00000   1.00000
5.5   1.6368e+000   6.11e-001   0.78952   1.00000   1.00000   1.00000
5.6   1.3577e+000   7.37e-001   0.72833   1.00000   1.00000   1.00000
5.7   1.1283e+000   8.86e-001   0.66389   1.00000   1.00000   1.00000
5.8   9.3937e-001   1.06e+000   0.59861   1.00000   1.00000   1.00000
5.9   7.8341e-001   1.28e+000   0.53459   1.00000   1.00000   1.00000
6.0   6.5438e-001   1.53e+000   0.47342   1.00000   1.00000   1.00000
6.1   5.4742e-001   1.83e+000   0.41624   1.00000   1.00000   1.00000
6.2   4.5856e-001   2.18e+000   0.36372   1.00000   1.00000   1.00000
6.3   3.8460e-001   2.60e+000   0.31618   1.00000   1.00000   1.00000
6.4   3.2292e-001   3.10e+000   0.27364   0.99999   1.00000   1.00000
6.5   2.7138e-001   3.68e+000   0.23594   0.99995   1.00000   1.00000
6.6   2.2824e-001   4.38e+000   0.20278   0.99982   1.00000   1.00000
6.7   1.9205e-001   5.21e+000   0.17379   0.99946   1.00000   1.00000
```

```
6.8   1.6164e-001   6.19e+000   0.14856   0.99856   0.99999   1.00000
6.9   1.3605e-001   7.35e+000   0.12670   0.99655   0.99995   1.00000
7.0   1.1447e-001   8.74e+000   0.10780   0.99250   0.99982   1.00000
7.1   9.6242e-002   1.04e+001   0.09149   0.98511   0.99947   1.00000
7.2   8.0824e-002   1.24e+001   0.07746   0.97276   0.99856   1.00000
7.3   6.7758e-002   1.48e+001   0.06538   0.95372   0.99648   1.00000
7.4   5.6669e-002   1.76e+001   0.05500   0.92637   0.99218   1.00000
7.5   4.7242e-002   2.12e+001   0.04608   0.88955   0.98407   1.00000
7.6   3.9217e-002   2.55e+001   0.03841   0.84271   0.97003   1.00000
7.7   3.2374e-002   3.09e+001   0.03182   0.78604   0.94757   1.00000
7.8   2.6531e-002   3.77e+001   0.02616   0.72040   0.91412   1.00000
7.9   2.1534e-002   4.64e+001   0.02129   0.64725   0.86738   1.00000
8.0   1.7254e-002   5.80e+001   0.01710   0.56840   0.80575   0.99999
8.1   1.3584e-002   7.36e+001   0.01349   0.48583   0.72851   0.99995
8.2   1.0433e-002   9.59e+001   0.01038   0.40149   0.63603   0.99968
8.3   7.7226e-003   1.29e+002   0.00769   0.31720   0.52962   0.99817
8.4   5.3890e-003   1.86e+002   0.00537   0.23449   0.41141   0.99039
8.5   3.3770e-003   2.96e+002   0.00337   0.15462   0.28408   0.95330
8.6   1.6400e-003   6.10e+002   0.00164   0.07853   0.15055   0.79013
8.7   1.3853e-004   7.22e+003   0.00014   0.00690   0.01375   0.12884
```

Appendix D: Area-Specific Hazard Information File: Karachi Area

```
=====================================================================
 File       : Karachi_ha2_160408.doc
 Created on : 16-Apr-2008 11:01:43
=====================================================================

 SEISMIC HAZARD ASSESSMENT FOR SELECTED AREA
 FROM PRE-HISTORIC, HISTORIC, and INCOMPLETE DATA
 ORIGIN TIME OF PRE-HISTORIC EVENTS CAN BE UNCERTAIN

 FLOW OF SEISMIC EVENTS IS MODELED BY BAYESIAN-BASED EQUATIONS
 WHICH ACCOUNT UNCERTAINTY OF SEISMIC HAZARD MODEL

 HAZARD PARAMETERS BEATA AND LAMBDA ARE CALCULATED SIMULTANEOUSLY
 MAGNITUDE ERRORS ARE DISTRIBUTED NORMALLY
 RANGE OF MAGNITUDE INTEGRATION : < m_min, m_max >

 REGONAL MAXIMUM MAGNITUDE CAN BE ESTIMATED ACCORDING TO :

     (1) Gibowicz-Kijko (1994)
     (2) Gibowicz-Kijko-Bayes
     (3) Kijko-Sellevoll (1989)
     (4) Kijko-Sellevoll-Bayes
     (5) Tate-Pisarenko
     (6) Tate-Pisarenko-Bayes
     (7) Non-Parametric (Gaussian) procedure

 Theory of the HAZARD evaluation procedure is given in:

    "Estimation of earthquake hazard parameters
     from Incomplete data files", Part II.
     by A. Kijko and M.A. Sellevoll (1992)
     Bull. Seism. Soc. Am. vol.82, p.120-134.

  and

    "Parametric-Historic" procedure for probabilistic
     seismic hazard analysis. Part I. Assessment
     of maximum regional magnitude m_max.
     by A. Kijko and G. Graham (1998),
     Pure App. Geophys, vol. 152, p.413-442.

=====================================================================
 PROGRAM NAME     : HA2 (H = Hazard; A = Area)
 WRITTEN          : 15 AUG 1999 by A.Kijko
 REVISION 1       : 21 MAR 2005 by A.Kijko
 REVISION 2       : 25 JUL 2005 by J.Ramperthap
 REVISION 3       : 15 AUG 2005 by J.Ramperthap
 REVISION 4       : 22 JUN 2006 by A.Kijko
 VERSION          : 2.05
=====================================================================

 For more information, contact A.Kijko or M.Bejaichund or J.Ramperthap,
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 Phone  :  +(27) 12 8411201, 8411454 or 8411180
 Fax    :  +(27) 12 8411224
 E-mail :   kijko@geoscience.org.za, mayshree@geoscience.org.za or
            jasonr@geoscience.org.za

=====================================================================

 NAME OF THE AREA: Karachi


                       HISTORIC DATA:
                    ********************

 NAME OF HISTORIC DATA FILE: e

 BEGINING OF HISTORIC DATA (Y-M-D) = 1435 1 1
 END      OF HISTORIC DATA (Y-M-D) = 2005 1 15
 NUMBER OF HISTORIC EQ-s           = 55
```

```
"THRESHOLD" MAG. OF HISTORIC EQ-s = 5
STANDARD ERROR OF EQ-e MAGNITUDE  = 0.25

1440   6  15  6.5
1483   2  18  7.7
1819   6  16  8.3
1853   5   4  6.5
1909  10  20  7.2
1923   9  22  6.9
1925  12  18  5.5
1928   3   8  5.0
1935   5  30  7.5
1945  11  27  8.3
1947   8   5  7.6
1949   4  24  6.5
1954   8  20  5.0
1956  10  31  6.8
1960   4  24  6.0
1961   6  11  7.2
1962  11   6  5.5
1963   7  29  5.2
1965   6  21  6.0
1968   6  23  5.3
1970   3  23  5.1
1971   4  12  6.0
1972   4  10  7.1
1973   1  20  5.6
1974  10   4  5.9
1975  10   3  6.7
1976   4  22  6.0
1977   3  21  7.0
1978   3  16  5.9
1979   1  10  6.1
1980  11  28  5.5
1981   7  28  7.3
1982  12  19  5.9
1983   4  18  6.5
1984   8   6  5.7
1985   5   6  5.6
1986   7  12  5.7
1987   4  29  5.9
1988   8  11  6.1
1989   5  27  5.8
1990  11   6  6.7
1991   5  22  5.7
1992   4  24  6.2
1993  11  16  5.6
1994   2  24  6.3
1995   5  31  5.6
1996   2  26  5.5
1997   2  27  7.3
1998   3  14  6.9
1999   3   4  6.6
2000   6   4  6.0
2001   1  26  8.0
2002   7  13  5.8
2003  12  26  6.8
2004   1  14  5.4

LARGEST EQ IN HISTORIC CATALOG = 8.3


PROVISION FOR INDUCED SEISMICITY : NOT REQUIRED
===============================================


                        ***

TIME SPAN OF WHOLE CATALOG           = 570.03 [Y]
MAXIMUM MAGNITUDE IN THE CATALOG     = 8.3
SD OF MAXIMUM OBSERVED MAGNITUDE     = 0.25
MODEL UNCERTAINTY OF BETA            = 25 [per cent]
MODEL UNCERTAINTY OF LAMBDA          = 25 [per cent]

CALCULATIONS ARE PERFORMED FOR MINIMUM MAGNITUDE Mmin = 5.00


PRIOR VALUE OF PARAMETER b           = 1
SD OF PRIOR b-VALUE                  = 0.1
```

```
                      RESULTS
                   *************

 BETA   = 2.08 +-  0.16 (b = 0.90 +- 0.07)
 LAMBDA = 2.523 +- 0.456 (for Mmin = 5.00)
 Mmax   = 8.44 +- 0.29  (for Mmax obs. = 8.30 +- 0.25)

 Maximum Regional Magnitude Mmax is calculated
 according to procedure by Kijko-Sellevoll-Bayes


Mag      Lambda         RP          Prob(T = 1  50   100   1000)

5.0   2.5234e+000   3.96e-001   0.90397   1.00000   1.00000   1.00000
5.1   2.0505e+000   4.88e-001   0.85476   1.00000   1.00000   1.00000
5.2   1.6705e+000   5.99e-001   0.79585   1.00000   1.00000   1.00000
5.3   1.3641e+000   7.33e-001   0.72993   1.00000   1.00000   1.00000
5.4   1.1166e+000   8.96e-001   0.66018   1.00000   1.00000   1.00000
5.5   9.1598e-001   1.09e+000   0.58964   1.00000   1.00000   1.00000
5.6   7.5301e-001   1.33e+000   0.52089   1.00000   1.00000   1.00000
5.7   6.2028e-001   1.61e+000   0.45587   1.00000   1.00000   1.00000
5.8   5.1192e-001   1.95e+000   0.39583   1.00000   1.00000   1.00000
5.9   4.2324e-001   2.36e+000   0.34147   1.00000   1.00000   1.00000
6.0   3.5050e-001   2.85e+000   0.29299   0.99999   1.00000   1.00000
6.1   2.9069e-001   3.44e+000   0.25030   0.99997   1.00000   1.00000
6.2   2.4141e-001   4.14e+000   0.21306   0.99988   1.00000   1.00000
6.3   2.0071e-001   4.98e+000   0.18083   0.99959   1.00000   1.00000
6.4   1.6703e-001   5.99e+000   0.15309   0.99879   0.99999   1.00000
6.5   1.3910e-001   7.19e+000   0.12933   0.99690   0.99996   1.00000
6.6   1.1588e-001   8.63e+000   0.10905   0.99288   0.99984   1.00000
6.7   9.6558e-002   1.04e+001   0.09178   0.98529   0.99948   1.00000
6.8   8.0435e-002   1.24e+001   0.07710   0.97234   0.99852   1.00000
6.9   6.6958e-002   1.49e+001   0.06463   0.95216   0.99628   1.00000
7.0   5.5672e-002   1.80e+001   0.05406   0.92318   0.99158   1.00000
7.1   4.6203e-002   2.16e+001   0.04509   0.88443   0.98273   1.00000
7.2   3.8245e-002   2.61e+001   0.03748   0.83574   0.96759   1.00000
7.3   3.1544e-002   3.17e+001   0.03102   0.77781   0.94381   1.00000
7.4   2.5893e-002   3.86e+001   0.02554   0.71203   0.90927   1.00000
7.5   2.1118e-002   4.74e+001   0.02088   0.64031   0.86243   1.00000
7.6   1.7078e-002   5.86e+001   0.01692   0.56477   0.80262   0.99999
7.7   1.3653e-002   7.32e+001   0.01355   0.48752   0.73022   0.99995
7.8   1.0746e-002   9.31e+001   0.01068   0.41048   0.64655   0.99973
7.9   8.2734e-003   1.21e+002   0.00824   0.33529   0.55365   0.99873
8.0   6.1681e-003   1.62e+002   0.00615   0.26322   0.45404   0.99458
8.1   4.3725e-003   2.29e+002   0.00436   0.19519   0.35039   0.97905
8.2   2.8389e-003   3.52e+002   0.00283   0.13179   0.24527   0.92671
8.3   1.5270e-003   6.55e+002   0.00153   0.07334   0.14099   0.76741
8.4   4.0332e-004   2.48e+003   0.00040   0.01995   0.03948   0.32855
```

Appendix E: Area-Specific Hazard Information File: South Sandwich Area

```
======================================================================
 File       : South_Sandwich_ha2_21042008.doc
 Created on : 21-Apr-2008 08:53:00
======================================================================

 SEISMIC HAZARD ASSESSMENT FOR SELECTED AREA
 FROM PRE-HISTORIC, HISTORIC, and INCOMPLETE DATA
 ORIGIN TIME OF PRE-HISTORIC EVENTS CAN BE UNCERTAIN

 FLOW OF SEISMIC EVENTS IS MODELED BY BAYESIAN-BASED EQUATIONS
 WHICH ACCOUNT UNCERTAINTY OF SEISMIC HAZARD MODEL

 HAZARD PARAMETERS BEATA AND LAMBDA ARE CALCULATED SIMULTANEOUSLY
 MAGNITUDE ERRORS ARE DISTRIBUTED NORMALLY
 RANGE OF MAGNITUDE INTEGRATION : < m_min, m_max >

 REGONAL MAXIMUM MAGNITUDE CAN BE ESTIMATED ACCORDING TO :

     (1) Gibowicz-Kijko (1994)
     (2) Gibowicz-Kijko-Bayes
     (3) Kijko-Sellevoll (1989)
     (4) Kijko-Sellevoll-Bayes
     (5) Tate-Pisarenko
     (6) Tate-Pisarenko-Bayes
     (7) Non-Parametric (Gaussian) procedure

 Theory of the HAZARD evaluation procedure is given in:

    "Estimation of earthquake hazard parameters
     from Incomplete data files", Part II.
     by A. Kijko and M.A. Sellevoll (1992)
     Bull. Seism. Soc. Am. vol.82, p.120-134.

  and

    "Parametric-Historic" procedure for probabilistic
     seismic hazard analysis. Part I. Assessment
     of maximum regional magnitude m_max.
     by A. Kijko and G. Graham (1998),
     Pure App. Geophys, vol. 152, p.413-442.

======================================================================
 PROGRAM NAME     : HA2 (H = Hazard; A = Area)
 WRITTEN          : 15 AUG 1999 by A.Kijko
 REVISION 1       : 21 MAR 2005 by A.Kijko
 REVISION 2       : 25 JUL 2005 by J.Ramperthap
 REVISION 3       : 15 AUG 2005 by J.Ramperthap
 REVISION 4       : 22 JUN 2006 by A.Kijko
 VERSION          : 2.05
======================================================================

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 E-mail :   kijko@geoscience.org.za, mayshree@geoscience.org.za or
            jasonr@geoscience.org.za

======================================================================

 NAME OF THE AREA: South Sandwich


                       HISTORIC DATA:
                    ********************

 NAME OF HISTORIC DATA FILE: e

 BEGINING OF HISTORIC DATA (Y-M-D) = 1973 1 1
```

```
END      OF HISTORIC DATA (Y-M-D) = 2005 1 8
NUMBER OF HISTORIC EQ-s           = 26
"THRESHOLD" MAG. OF HISTORIC EQ-s = 5.5
STANDARD ERROR OF EQ-e MAGNITUDE  = 0.1

1973  10   6  7.5
1974  11  20  6.5
1975  11  29  6.2
1977   8  26  7.1
1982   5   7  6.7
1983  10  22  7.0
1985   5  15  6.5
1986   4  14  6.3
1987   1  30  7.0
1988  11   1  6.1
1990   5   9  6.5
1991  12  27  7.2
1992  11  21  6.6
1993   3  10  6.7
1994   7  25  6.6
1995   4  14  6.5
1996   1  22  6.2
1997  10   5  6.3
1998   8  29  6.0
1999  10  18  6.6
2000  11   7  6.8
2001   4  13  6.2
2002  11  15  6.6
2003   9  30  6.0
2004   9   6  6.9
2005   1   8  6.0

LARGEST EQ IN HISTORIC CATALOG = 7.5


PROVISION FOR INDUCED SEISMICITY : NOT REQUIRED
===============================================


                       ***

TIME SPAN OF WHOLE CATALOG           = 32.02 [Y]
MAXIMUM MAGNITUDE IN THE CATALOG     = 7.5
SD OF MAXIMUM OBSERVED MAGNITUDE     = 0.2
MODEL UNCERTAINTY OF BETA            = 25 [per cent]
MODEL UNCERTAINTY OF LAMBDA          = 25 [per cent]

CALCULATIONS ARE PERFORMED FOR MINIMUM MAGNITUDE Mmin = 5.50


PRIOR VALUE OF PARAMETER b           = 1
SD OF PRIOR b-VALUE                  = 0.1

                     RESULTS
                  *************

BETA   = 2.47 +-  0.22 (b = 1.07 +- 0.09)
LAMBDA = 8.415 +- 2.140 (for Mmin = 5.50)
Mmax   = 7.64 +- 0.24  (for Mmax obs. = 7.50 +- 0.20)

Maximum Regional Magnitude Mmax is calculated
according to procedure by Kijko-Sellevoll-Bayes


Mag      Lambda         RP          Prob(T = 1  50   100   1000)

5.5   8.4153e+000   1.19e-001   0.99884   1.00000   1.00000   1.00000
5.6   6.5678e+000   1.52e-001   0.99593   1.00000   1.00000   1.00000
5.7   5.1409e+000   1.95e-001   0.98841   1.00000   1.00000   1.00000
5.8   4.0347e+000   2.48e-001   0.97262   1.00000   1.00000   1.00000
5.9   3.1738e+000   3.15e-001   0.94472   1.00000   1.00000   1.00000
6.0   2.5014e+000   4.00e-001   0.90213   1.00000   1.00000   1.00000
6.1   1.9743e+000   5.07e-001   0.84459   1.00000   1.00000   1.00000
6.2   1.5598e+000   6.41e-001   0.77425   1.00000   1.00000   1.00000
6.3   1.2326e+000   8.11e-001   0.69500   1.00000   1.00000   1.00000
6.4   9.7358e-001   1.03e+000   0.61136   1.00000   1.00000   1.00000
6.5   7.6785e-001   1.30e+000   0.52763   1.00000   1.00000   1.00000
6.6   6.0395e-001   1.66e+000   0.44724   1.00000   1.00000   1.00000
6.7   4.7298e-001   2.11e+000   0.37257   1.00000   1.00000   1.00000
```

```
6.8   3.6801e-001   2.72e+000   0.30500   1.00000   1.00000   1.00000
6.9   2.8365e-001   3.53e+000   0.24509   0.99996   1.00000   1.00000
7.0   2.1566e-001   4.64e+000   0.19283   0.99974   1.00000   1.00000
7.1   1.6071e-001   6.22e+000   0.14778   0.99851   0.99999   1.00000
7.2   1.1619e-001   8.61e+000   0.10932   0.99296   0.99984   1.00000
7.3   8.0020e-002   1.25e+001   0.07672   0.97187   0.99848   1.00000
7.4   5.0565e-002   1.98e+001   0.04923   0.90438   0.98765   1.00000
7.5   2.6519e-002   3.77e+001   0.02615   0.72025   0.91403   1.00000
7.6   6.8404e-003   1.46e+002   0.00682   0.28710   0.48820   0.99664
```

Appendix F: Area-Specific Hazard Information File: Sumatra Area

```
=====================================================================
 File       : Sumatra_ha2_21042008.doc
 Created on : 21-Apr-2008 08:47:29
=====================================================================

 SEISMIC HAZARD ASSESSMENT FOR SELECTED AREA
 FROM PRE-HISTORIC, HISTORIC, and INCOMPLETE DATA
 ORIGIN TIME OF PRE-HISTORIC EVENTS CAN BE UNCERTAIN

 FLOW OF SEISMIC EVENTS IS MODELED BY BAYESIAN-BASED EQUATIONS
 WHICH ACCOUNT UNCERTAINTY OF SEISMIC HAZARD MODEL

 HAZARD PARAMETERS BEATA AND LAMBDA ARE CALCULATED SIMULTANEOUSLY
 MAGNITUDE ERRORS ARE DISTRIBUTED NORMALLY
 RANGE OF MAGNITUDE INTEGRATION : < m_min, m_max >

 REGONAL MAXIMUM MAGNITUDE CAN BE ESTIMATED ACCORDING TO :

     (1) Gibowicz-Kijko (1994)
     (2) Gibowicz-Kijko-Bayes
     (3) Kijko-Sellevoll (1989)
     (4) Kijko-Sellevoll-Bayes
     (5) Tate-Pisarenko
     (6) Tate-Pisarenko-Bayes
     (7) Non-Parametric (Gaussian) procedure

 Theory of the HAZARD evaluation procedure is given in:

    "Estimation of earthquake hazard parameters
     from Incomplete data files", Part II.
     by A. Kijko and M.A. Sellevoll (1992)
     Bull. Seism. Soc. Am. vol.82, p.120-134.

  and

    "Parametric-Historic" procedure for probabilistic
     seismic hazard analysis. Part I. Assessment
     of maximum regional magnitude m_max.
     by A. Kijko and G. Graham (1998),
     Pure App. Geophys, vol. 152, p.413-442.

=====================================================================
 PROGRAM NAME     : HA2 (H = Hazard; A = Area)
 WRITTEN          : 15 AUG 1999 by A.Kijko
 REVISION 1       : 21 MAR 2005 by A.Kijko
 REVISION 2       : 25 JUL 2005 by J.Ramperthap
 REVISION 3       : 15 AUG 2005 by J.Ramperthap
 REVISION 4       : 22 JUN 2006 by A.Kijko
 VERSION          : 2.05
=====================================================================

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 Fax    :  +(27) 12 8411224
 E-mail :   kijko@geoscience.org.za, mayshree@geoscience.org.za or
            jasonr@geoscience.org.za

=====================================================================

 NAME OF THE AREA: Sumatra


                       HISTORIC DATA:
                    ********************

 NAME OF HISTORIC DATA FILE: e

 BEGINING OF HISTORIC DATA (Y-M-D) = 1973 1 1
 END      OF HISTORIC DATA (Y-M-D) = 2005 2 2
 NUMBER OF HISTORIC EQ-s           = 33
```

```
 "THRESHOLD" MAG. OF HISTORIC EQ-s = 5.5
 STANDARD ERROR OF EQ-e MAGNITUDE  = 0.1

 1973   4   7  6.6
 1974  12   4  6.9
 1975  10   1  7.0
 1976   6  20  7.0
 1977   5  25  6.0
 1978   6  24  6.4
 1979   9  29  6.8
 1980  10   8  6.3
 1981  11   8  5.8
 1982   1  20  6.3
 1983   4   4  6.8
 1984  11  17  7.4
 1985  12  27  6.6
 1986   6  19  5.9
 1987   4  25  6.6
 1988   8  17  6.1
 1989   7  20  5.9
 1990  11  15  6.8
 1991   7   2  6.2
 1992   9   2  6.7
 1993   8   4  6.5
 1994   2  15  7.0
 1995  11   8  7.1
 1996  10  10  6.3
 1997   3  17  6.4
 1998   4   1  7.0
 1999  12  21  6.5
 2000   6   4  8.3
 2001   2  13  7.4
 2002  11   2  7.6
 2003   5  14  6.0
 2004  12  26  9.0
 2005   1   1  6.7

 LARGEST EQ IN HISTORIC CATALOG = 9


 PROVISION FOR INDUCED SEISMICITY : NOT REQUIRED
 ===============================================


                         ***

 TIME SPAN OF WHOLE CATALOG           = 32.09 [Y]
 MAXIMUM MAGNITUDE IN THE CATALOG     = 9
 SD OF MAXIMUM OBSERVED MAGNITUDE     = 0.2
 MODEL UNCERTAINTY OF BETA            = 25 [per cent]
 MODEL UNCERTAINTY OF LAMBDA          = 25 [per cent]

 CALCULATIONS ARE PERFORMED FOR MINIMUM MAGNITUDE Mmin = 5.50


 PRIOR VALUE OF PARAMETER b           = 1
 SD OF PRIOR b-VALUE                  = 0.1

                      RESULTS
                   *************

 BETA   = 2.36 +-  0.20 (b = 1.03 +- 0.09)
 LAMBDA = 9.183 +- 2.116 (for Mmin = 5.50)
 Mmax   = 9.20  (for Mmax obs. = 9.00 +- 0.20)

 Maximum Regional Magnitude Mmax is calculated
 according to procedure by Kijko-Sellevoll-Bayes

 Attempt to assess Mmax by chosen procedure was UNSUCCESFUL


Mag      Lambda         RP          Prob(T = 1  50   100   1000)

5.5   9.1830e+000   1.09e-001   0.99929   1.00000   1.00000   1.00000
5.6   7.2626e+000   1.38e-001   0.99749   1.00000   1.00000   1.00000
5.7   5.7629e+000   1.74e-001   0.99271   1.00000   1.00000   1.00000
5.8   4.5876e+000   2.18e-001   0.98229   1.00000   1.00000   1.00000
5.9   3.6633e+000   2.73e-001   0.96307   1.00000   1.00000   1.00000
6.0   2.9341e+000   3.41e-001   0.93239   1.00000   1.00000   1.00000
```

```
6.1   2.3568e+000   4.24e-001   0.88904   1.00000   1.00000   1.00000
6.2   1.8983e+000   5.27e-001   0.83369   1.00000   1.00000   1.00000
6.3   1.5331e+000   6.52e-001   0.76871   1.00000   1.00000   1.00000
6.4   1.2414e+000   8.06e-001   0.69747   1.00000   1.00000   1.00000
6.5   1.0076e+000   9.92e-001   0.62360   1.00000   1.00000   1.00000
6.6   8.1969e-001   1.22e+000   0.55039   1.00000   1.00000   1.00000
6.7   6.6828e-001   1.50e+000   0.48040   1.00000   1.00000   1.00000
6.8   5.4595e-001   1.83e+000   0.41541   1.00000   1.00000   1.00000
6.9   4.4684e-001   2.24e+000   0.35642   1.00000   1.00000   1.00000
7.0   3.6634e-001   2.73e+000   0.30386   1.00000   1.00000   1.00000
7.1   3.0079e-001   3.32e+000   0.25769   0.99998   1.00000   1.00000
7.2   2.4728e-001   4.04e+000   0.21760   0.99989   1.00000   1.00000
7.3   2.0349e-001   4.91e+000   0.18308   0.99962   1.00000   1.00000
7.4   1.6758e-001   5.97e+000   0.15356   0.99882   0.99999   1.00000
7.5   1.3806e-001   7.24e+000   0.12844   0.99678   0.99995   1.00000
7.6   1.1374e-001   8.79e+000   0.10715   0.99230   0.99981   1.00000
7.7   9.3662e-002   1.07e+001   0.08916   0.98355   0.99937   1.00000
7.8   7.7046e-002   1.30e+001   0.07398   0.96831   0.99814   1.00000
7.9   6.3269e-002   1.58e+001   0.06119   0.94424   0.99516   1.00000
8.0   5.1822e-002   1.93e+001   0.05042   0.90942   0.98877   1.00000
8.1   4.2292e-002   2.36e+001   0.04136   0.86276   0.97654   1.00000
8.2   3.4342e-002   2.91e+001   0.03372   0.80428   0.95545   1.00000
8.3   2.7698e-002   3.61e+001   0.02729   0.73505   0.92227   1.00000
8.4   2.2135e-002   4.52e+001   0.02188   0.65704   0.87421   1.00000
8.5   1.7468e-002   5.72e+001   0.01731   0.57276   0.80946   0.99999
8.6   1.3546e-002   7.38e+001   0.01345   0.48489   0.72756   0.99995
8.7   1.0245e-002   9.76e+001   0.01019   0.39602   0.62954   0.99964
8.8   7.4605e-003   1.34e+002   0.00743   0.30840   0.51769   0.99781
8.9   5.1085e-003   1.96e+002   0.00509   0.22385   0.39520   0.98813
9.0   3.1184e-003   3.21e+002   0.00311   0.14373   0.26570   0.94210
9.1   1.4317e-003   6.98e+002   0.00143   0.06894   0.13284   0.74621
9.2   2.2204e-016   4.50e+015   0.00000   0.00000   0.00000   0.00000
```

APPENDIX D:

Council for Geoscience Report: Potential Sources of Tsunami Along the South African Coast

POTENTIAL SOURCES OF TSUNAMI ALONG THE SOUTH AFRICAN COAST

By: D.L. Roberts

CGS Report Number: 2008 - 0220

CONFIDENTIAL

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	COUNCIL FOR GEOSCIENCE **(Western Cape Unit)**	REFERENCE: CGS REPORT 2008 - 0220
	NUCLEAR SITING INVESTIGATION PROGRAMME	REVISION 1
COPY No.	**POTENTIAL SOURCES OF TSUNAMI ALONG THE SOUTH AFRICAN COAST**	DATE OF RELEASE: 19/09/2008
		CONFIDENTIAL

AUTHORS			
			REVIEWED BY:
DR. D.L. ROBERTS			
ACCEPTED BY:	ACCEPTED BY:	ACCEPTED BY:	AUTHORISED BY:

REVISION	DESCRIPTION OF REVISION	DATE	MINOR REVISIONS APPROVAL
0		09-09-2008	
1	Minor changes on request by Stephan Luger, PRDW	19-09-2008	

Index ***Page***

Figures

Figure 1. *Locality map showing*

Figure 2. *Global DEM showing potential sources of tsunami along the South African coast.*

Figure 3. *Dwarskersbos on the west coast (see Figure 1 for location), scene of a possible tsunami in 1969.*

Figure 4. *Tide gauge records for Cape Town, Saldanha and Port Nolloth*

Figure 5. *The residual values of expected/measured tidal data from the west coast.*

Figure 6. *An example of atmospheric gravity waves enhanced by sunglint conditions.*

Figure 7. *Five minute interval data from SAWS's automatic weather station at Port Nolloth showing atmospheric gravity waves.*

Figure 8. *Tide gauge records for Coega Harbour on the southeast coast for the 2004 Sumatran seismogenic tsunami.*

Figure 9. *DEM showing the disposition of steep hillslopes comprising highly fractured and jointed Palaeozoic quartzites, possible sources of tsunamigenic rockfalls.*

Figure 10. *Precipitous cliffs comprising highly fractured and jointed Palaeozoic quartzites at the entrance to Hout Bay.*

Figure 11. *Major late Holocene landslide into the estuary of the Knysna River.*

1. Scope of the Study

The Council for Geoscience was requested by Prestedge Retief Dresner Wijnberg (Pty) Ltd to provide a report on the potential sources of tsunami along the coastline of South Africa. Special focus is on the west and southern coasts where planned nuclear facilities are to be sited. Sources of significant tsunamigenic capacity on global as well as regional and local scales are considered. The study specifically addresses the following questions:

- What is the relative magnitude of the threat posed by the various sources of tsunami?
- What segments of the coastline are at highest risk?
- To what extent can tsunami be predicted?
- What is the warning period(s) for tsunami?
- What actions can be taken in mitigation/adaptation to the threat posed by tsunami?

2. Introduction

The catastrophic tsunami of 26th December 2004 was caused by the massive earthquake on the Sumatra-Andaman Subduction Zone with moment magnitude (Mw) ~9.3. In total about 160 000 people were killed and more than 1 million displaced in South Asia and East Africa, reaffirming the devastating character of these phenomena (Iwan, 2006; Synolakis et al., 2007). Over the past few decades, several other significant global to regional scale tsunami have been recorded (Geist, 1998; Iwan, 2006). None approached the severity of the Sumatra event, but nonetheless have served to further emphasise the threat.

Numerical modelling designed to predict the sources, frequency and amplitude of tsunami that could impinge on the southern African coastal belt has been undertaken (Hartnady, 2005; Hartnady and Okal, in press). South Africa also participates in the

Intergovernmental Coordination Group with respect to the Indian Ocean Tsunami Warning and Mitigation System (IOTWS) initiative (A. Kijko, pers. comm.). The chief focus of previous work in southern Africa has been the threat represented by remote submarine seismicity, volcanicity and submarine slumps along the east coast (Kijko, pers. comm.; Hartnady and Okal, in press). This study extends and supplements this work by a consideration of submarine slumps along the west and southern coasts, in addition to cosmic impacts and the tsunamigenic threat posed by major rockfalls and landslides. The relationship between the coastal seismic record and submarine slumps in particular is examined.

3. Coastal Seismicity

Since earthquakes, whether directly or indirectly are the major trigger of tsunami (e.g. Salamon et al., 2007), it is appropriate to briefly review the seismic setting and history of events along the southern African coastline. The stable intraplate, trailing edge tectono-seismic model determined for the southern African coastline (Fig. 1) dictates general seismic quiescence (De Swardt, and Bennet, 1974; De Beer, 1983; Goedhart, 2007). However, in common with similar settings elsewhere a low frequency, low intensity background seismicity prevails (Fernandez and Shapiro, 1989; Theron, 1974). The current neotectonism is inherited from the complex early geodynamic history of southern Africa and modern seismicity tends to be concentrated along ancient lineaments of crustal weakness (De Beer, 1983; Hälbich, 1983; Partridge and Maud, 2000; Goedhardt, 2007).

Figure 1 summarises the modern and historic distribution of seismicity up to 1998 and prediction of future risk. A region of enhanced seismic activity centres around Cape Town, corresponding with the intense fracturing of the Cape Syntaxis northeast of this city, where faults are capable of at least Mw 6.3 events (Theron, 1974). Along the east coast two regions of notably enhanced seismic activity are apparent. In the south the zone of activity around the Mzimvubu River may be linked with the Mellville Thrust in the Namaqua-Natal tectonic province and shear zones of the Margate Terrain described by Thomas (1989). In the north around Sodwana Bay, the major Tugela Thrust Front is also spatially linked with modern seismicity (Fig. 1). In both instances, the onshore areas of enhanced seismicity coincide with offshore counterparts.

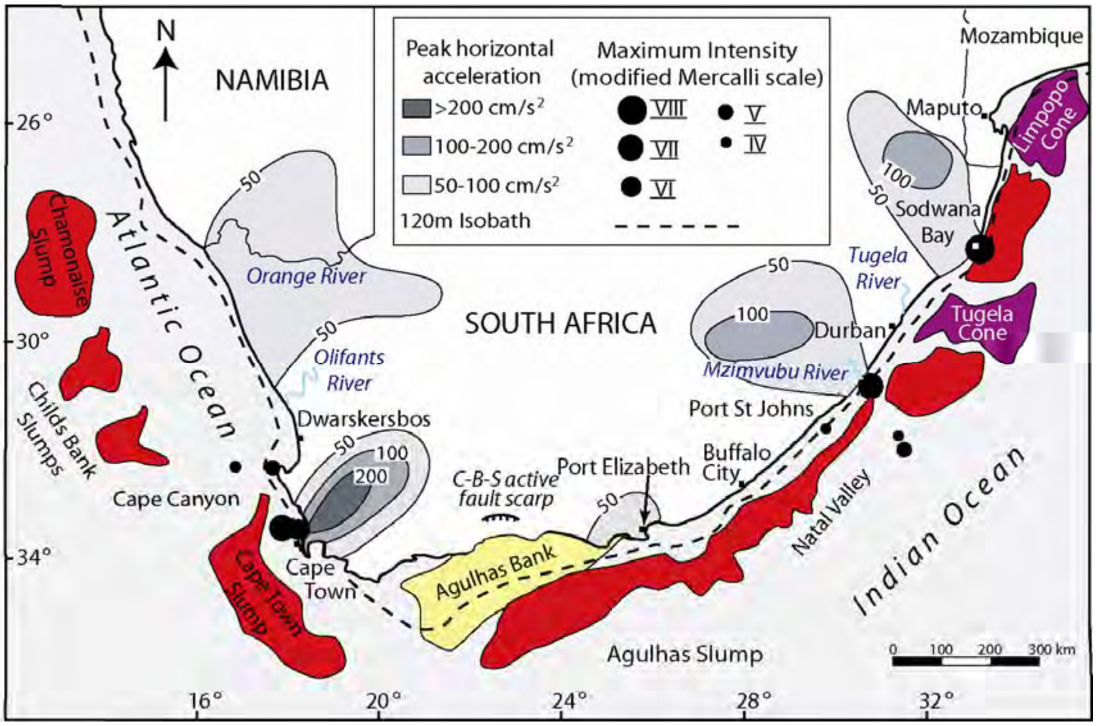

Figure 1. *Locality map showing offshore slumps and historical seismicity, illustrated by the contours of 10% probability of exceeding peak horizontal ground acceleration within 50 years (data from Fernandez and Shapiro, 1989). Historical offshore earthquake magnitude and location is indicated by solid circles. The slumps occur further offshore along the west coast owing to the greater width of the continental shelf.*

The historic and modern seismic record is currently being supplemented by deterministic palaeoseismic data (Goedhardt, 2007). Attention has focussed on the Ceres-Baviaanskloof-St. Croix fault system (C-B-S) that traverses the Cape Fold Belt for ~700 kilometres (Fig. 1), from Ceries in the west to Port Elizabeth in the east, before extending offshore to merge with the Agulhas-Falkland fracture zone (Goedhardt, 2007). West of Port Elizabeth, a scarp several metres high marks surface rupture along the C-B-S Fault recording a major early Holocene (~10 ka) seismic event of ~Mw7 (Hill, 1975; Goedhardt, 2007). Isostatic imbalances along the eastern segment of the fault may in the future give rise to large damaging earthquakes with accompanying surface rupture. Thus the entire southern coast is vulnerable to future seismicity (Goedhardt, 2007) and the risk is probably higher than indicated by Fernandez and Shapiro (1989) as shown in Figure 1.

4. Potential Sources of Tsunamigenesis

4.1 Cosmic impact

The catastrophic tsunamigenic capability of cosmic impacts is well documented e.g. the K-T event on the Yucatan Peninsula, which caused a major end-Createaceous global extinction (Smit et al., 1992). The geographic range is indiscriminate, posing an equal threat around the globe. Impacts by meteorites asteroids and comets of various scales and ages ranging from billions of years in the case of the massive Vredefort Dome in South Africa, to as recently as the Tunguska event in Siberia in 1908 have been reported (Turco et al., 1982; Bisschof, 1999). Although cosmic impacts large enough to cause significant tsunami are relatively rare, the recent Tunguska event, caused by the atmospheric explosion of a comet or meteorite, felled an estimated 80 million trees over 2,150 km^2. This served as a reminder that visitations from space constitute a major, potentially devastating threat (Turco et al., 1982).

New asteroids are identified and their orbital parameters quantified on an ongoing basis by NASA's Near-Earth Object Program (see NASA website at http://neo.jpl.nasa.gov/risk/). The maximum detected hazard is rated according to the Torino Impact Hazard Scale. According to this ten-point scale, a rating of zero indicates the event has "no likely consequences." A Torino Scale rating of 1 indicates an event that "merits careful monitoring" and higher ratings indicates progressively higher risk. The ‘Sentry System’ is a highly automated collision monitoring system that continually scans the current asteroid catalogue for possibilities of future impact with Earth over the next 100 years. Currently, no asteroids with a rating exceeding 0 (and therefore of significant tsunamigenic risk) are catalogued.

4.2 Remote Submarine Seismicity

This category of tsunamigenisis refers to waves generated by rapid displacement along submarine faults. Because of the quiescent trailing edge, intra-plate tectonic setting of the subcontinent (see section 3), it would appear that teletsunami from remote sources (plate boundaries) pose the greatest threat (Synolakis et al., 2007). The earliest reported tsunami by remote submarine seismicity that impinged on South African shores was spawned by the ~Mw 9.5 earthquake off the Chilean coast on May 22, 1960 (the strongest ever recorded). The Chilean event was recorded globally, including Mossel Bay, South Africa and in the Atlantic Ocean at Luderitz, Namibia (Van Dorn, 1987). The most imminent threat to the southeastern South African seaboard is posed by major earthquakes (Mw > 9 2) along the fast-moving convergent plate-boundaries at the Sunda Trench between Indonesia and Burma, and the Makran Trench bordering Pakistan and Iran (Fig. 2). It has also been suggested that there is a particularly high probability that a large seismic event in the southern part of the Sumatra Subduction Zone off the Mentawai Islands may source a large teletsunami (McCloskey et al., 2006; Okal et al., 2007; Hartnady and Okal, in press).

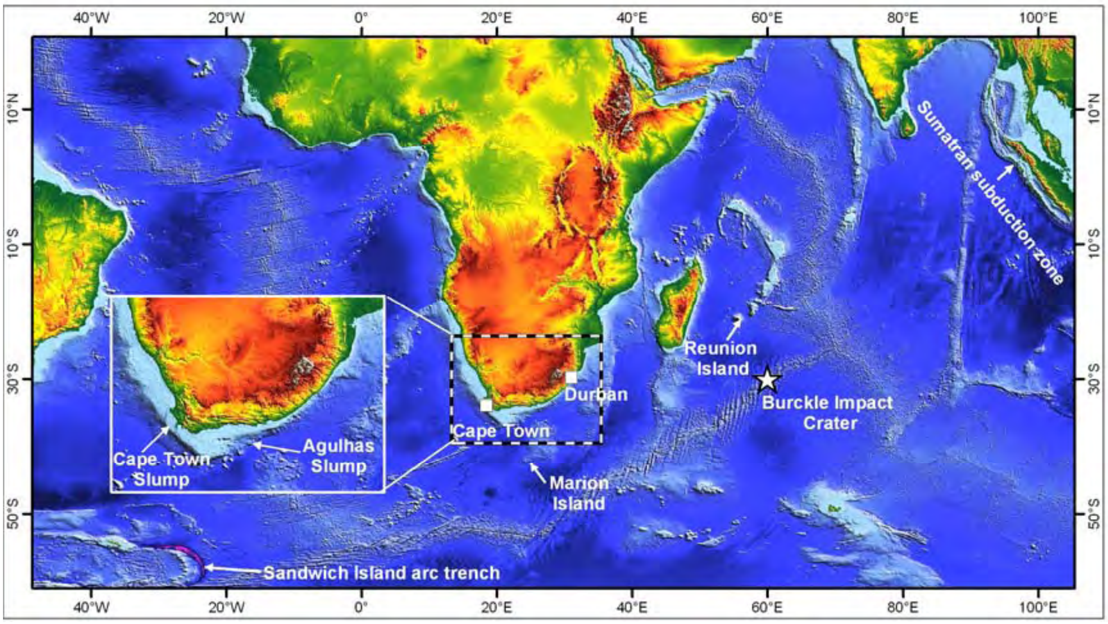

Figure 2. *Global DEM showing potential sources of tsunami along the South African coast. These include subsea seismogenic, volcanogenic, bolide impact and submarine slumps. The Cape Town and Agulhas slumps are apparent (inset).*

The Sumatran Subduction Zone generated the tsunami of 26th December 2004, significant waves from which were recorded by South African tide gauges on the Indian Ocean coast, with a maximum of wave height of ~2.7 m at Port Elizabeth. Apparently, the actual wave height was even higher but the wave crest was truncated due to instrumention factors (Rabinovich and Thomson, 2007). Lesser waves arrived at Richards Bay (1.5 m) ~100 km south of Sodwana Bay, Buffalo City (1.3 m) and 1.6 m at Mossel Bay 180 km west of Port Elizabeth (Fig. 1). Maximum wave heights on the Atlantic coast were much smaller, with 0.75 m at Cape Town, dwindling to 0.5 m at Port Nolloth, 80 km south of the Orange River (Fig. 1). These waves coincided with the calculated arrival time of the Sumatran tsunami (Rabinovich, and Thomson, 2007). Numerous anecdotal accounts of abnormal high tides on beaches and bores moving upstream in rivers were reported in the media. Anomalous drawdown of sea level was experienced at Port Elizabeth, resulting in the drowning of a person, the most distant fatality recorded from the Sumatran tsunami (Rabinovich, and Thomson, 2007).

The Sumatran event has emphatically demonstrated that seismogenic teletsunami from remote sources can impinge on the southern African coastline with telling effect. Although little damage was reported, had the largest amplitude wave arrival coincided with abnormal high tides (astronomical/storm surge), the resulting cumulative inundation could well have been significant. (Okal et al., 2007).

The recent tsunamigenic Bengkulu Earthquake (Mw 8.4) of 12 September 2007 generated an extended series of waves over the period 12-14 September 2007, reaching a maximum amplitude of ~0.4 m at Port Elizabeth. This tsunami was predictively modelled in real-time during its propagation across the Indian Ocean, (Hartnady and Okal, in press).

The intra-oceanic South Sandwich Island subduction zone (SSSZ) and associated forearc is situated in the southwestern Atlantic (Fig. 2). It represents the closest source of high-frequency, high-intensity subsea seismicity which could threaten the west coast of southern Africa. The SSSZ shows a high frequency of earthquakes greater than Mw 5. A large earthquake (~Mw 7.3) with an epicentre on the South Sandwich Fracture Zone occurred on 2 January 2006, ~400km southeast of the South Sandwich Islands (USGS, 2006).

This fault forms part of the boundary between the South American and Antarctic Plates. Since the major displacement was horizontal, no tsunami ensued and as yet no historical tsunami have been reported from this source (USGS, 2006). However, a multichannel seismic transect across the mid-forearc revealed a 1.2 km-high fault scarp associated with a 20 km wide tilted block, indicating large-scale gravitational collapse (Larter et al., 2003). This suggests possible past tsunamigenic capacity, but a tectonic environment of relatively low regional interplate stress may mitigate this propensity (Larter et al., 2003). The threat posed by seismicity in the intra-oceanic South Sandwich Island Arc and associated forearc subduction zone is uncertain and requires further assessment.

4.3 Submarine slides and slumps

4.3.1 Global events

Many reports have indicated that submarine slides and slumps can induce large and damaging tsunami on local to regional scales (Bugge et al., 1988; Bondevik et al. 1997; Tippin et al., 2003). It is instructive to briefly review an example from the literature of a tsunami produced by offshore slumping. The Storegga submarine slump off Norway is chosen here, as this should illuminate the threat posed by tsunamigenic offshore sediment slumping in the southern African context (Dingle et al. 1983).

The Storegga submarine slump situated in the North Sea off the passive Norwegian coast is one of the largest known Holocene examples (Brugge et al., 1988; Bondevik et al. 1997). Approximately 3500 km^3 of sediment was displaced, generating a tsunami that caused widespread inundations in Norway, the Faroe Islands, the Shetlands Islands and Scotland, dated to ~8100 calendar years BP. The maximum estimated runup exceeded 20 m, recorded in the Shetlands Islands (Bondevik et al., 1997). Seismicity was considered to have been the direct triggering mechanism of the slump.

4.3.2 South African submarine slumps

Seismic profiles along the southern African continental shelf have revealed widespread episodic injections of allochthonous masses into the deep sedimentary basins, including submarine slides and slumps (Dingle 1971; 1977; Summerhayes et al., 1979). Various phases of slumping on massive scales including late Mesozoic (148 Ma-65 Ma), early to late Tertiary (65 Ma-1.8 Ma) and possibly Quaternary (1.8 Ma-present), have been documented (Fig. 1) and have been largely instrumental in the morphogenesis of the continental margin (Dingle, 1977; Dingle, et al.1987; Ben-Avraham and Rogers,1992; Niemi, et al., 2000;. Reznikov et al., 2005).

Sediment is readily transported across the steep and narrow eastern shelf to be deposited in the adjacent Natal Valley, via a complex variety of processes including the migration of large bedforms, slumping, debris flow, turbidity currents and slope wasting. Widespread canyon development aids the sediment transfer. In contrast; little sediment from the few perennial rivers crosses the broader west coast shelf and sedimentation into the deep ocean basin is dominated by submarine slides and slumping; canyon development is muted, with the exception of the Cape Canyon (Dingle, 1977; Dingle, et al.1987; Ben-Avraham and Rogers,1992; Niemi, et al., 2000;. Reznikov et al, 2005.). However, during relative sea level lowstands rivers deposit their load nearer the shelf break, enhancing instability and propensity to slope failure. The shoreline during the Last Glacial Maximum (LGM) was at 120 m below sea level (Rogers, 1982), indicated in Figure 1 as the 120 m isobath. This shows that rivers debouched closer to the regions of intense slumping on the southern and east coasts than on the west coast. Other possible triggers of offshore slumps include overpressured formations and erosion by geostrophic currents (Dingle, 1977; Dingle, et al.1987; Westall, 2006).

Along the coastal stretch from the Orange River in the northwest to Cape Agulhas in the southeast, Dingle (1980) and Dingle et al. (1987) identified four major foci of submarine slides and slumps (Fig. 1): the Chamaise Slump relating to the Orange River allochthonous sediment pile; the Childs Bank Slumps; the Cape Town Slump which is associated with the Cape Canyon; and the massive Agulhas Slump. In the latter, about 340, 000 km^2 of continental rise and slope have been affected by relatively recent (late Cenozoic: 25 Ma-present) slumping. Over large areas of the Chamais, Cape Town and Agulhas slumps, notable thicknesses of sediment ranging up to 750 m are were involved. Because of their proximity to populated areas, attention here is focussed on the Cape Town and Agulhas structures.

The elongate Cape Town slump is only ~120 km wide (Fig. 1), but extends for least 400 km off the southwestern extremity of southern Africa (Dingle, 1980). It is associated with the Cape Canyon (Fig. 1) whose origin may stem from the late Tertiary (45 Ma-1.8 Ma) confluence of the Orange and Olifants Rivers, exiting near the present Olifants River Mouth. Typical cross sections of the Cape Town slump show an oversteepened continental slope with large rotated blocks up to 450 m thick and several kilometres in width at the foot. Extensive sediment fans have shifted the foot of the continental slope some 130 km basinwards (Dingle 1977, 1980).

The elongate Agulhas Slump on the southern coast is one of the largest in the world, extending for ~750 km (Fig. 1), with a displaced volume of ~20, 000 km^3 (Dingle, 1977, 1980). The structure is dammed on the western aspect by the Alguhas-Falkland fracture zone ridge and distally has spilled into the oceanic basin (Natal Valley). The Agulhas Slump is considered a geologically instantaneous feature, involving Mesozoic (148 Ma-65 Ma) and Cenozoic (65 Ma-present) strata (Dingle 1977, 1980).

According to Dingle (1977, 1980) the Agulhas and Cape Town slumps both involved Pliocene sediments and may therefore be Quaternary (1.8 Ma-present) in age (further supported by the ‘fresh’ appearance of slumped material, with little modification by subsequent erosion). Wigley and Compton (2006) suggested that the main slumping associated with the Cape Town structure dated to the late Quaternary (~120 ka-present). Slumps north of Luderitz off the Namibian coast were dated by radiocarbon to 50,000-25,000 years BP i.e. Late Pleistocene (~130 ka-10 ka) (Summerhayes et al., 1979). It appears likely, therefore, that much of the slumping along the west and southwest coasts relates to the latter part of the late Cenozoic (25 Ma-present).

In the offshore stretch from Port Elizabeth to Port St. Johns (Fig. 1) a relatively narrow belt of slumping is evident. In the latter region, a lineament with a right lateral offset of ~3 km plays a major role in the development of the slumping (Dingle et al., 1987). Some of these features may date from the Quaternary (1.8 Ma-present) (Dingle and Robson, 1985). Northwards from Port St. Johns extending up to Maputo, a series of large slumped areas and sediment cones related to major river mouths are developed. These formed in response to the large size and high sediment load of the east-flowing rivers along this humid subtropical coastal stretch.

4.3.3 Tsunami risk from submarine slumping

As noted above, seismicity has been widely implicated in triggering of submarine slumping in the global context (Bugge et al., 1988 Bondevik et al. 1997; Tippin et al., 2003; Salomon et al., 2007) and probably locally (Dingle 1980; Summerhayes et al.,1979). Both onshore and offshore earthquakes may be involved with possible ancillary factors such as overpressure from gas hydrates, undercutting by ocean currents and fluvial deposition on the distal shelf during glacio-eustatic lowstands (Dingle 1977; 1980; Summerhayes et al., 1979; Wigley and Compton, 2006). The high rates of terrigenous sediment input and steepness of the sheared margin further augments predisposition for mass sediment mobilisation along the east coast (Hartnady, 2005).

The Cape Slump ranks among the largest along the west coast and coincides with the seismically most active region in South Africa, both on- and offshore (Fig. 1). Onshore earthquakes in this region which exceeded Mw 6 in magnitude took place in 1809 and 1969 (Theron 1974; Goedhart, 2007) and offshore seismicity is also evident (Fig. 1). Thus the confluence of several considerations elevate the vulnerability of the coastal segment around Cape Town to slump-generated tsunami, including: evidence for major (possibly Quaternary: 1.8 Ma-present) submarine slumping; evidence for possible recent slump-generated tsunamigenesis; the exceptional intensity and frequency of seismicity in the southern African context; the low relief coastal plain in some areas; and high population density. The Chamaise Slump off the Orange River is associated with moderate seismicity (Fig. 1) and taking cognisance of the low population density is a relatively low risk area.

As noted above, the Agulhas Slump on the southern coast is one of the largest in the world. Seismicity related to the adjacent Algulhas-Falkland fracture zone may have triggered this massive slope failure (Dingle 1977). Although the southern coast is not a focus of historical seismicity (Fig. 1), the C-B-S fault system that traverses the Cape Fold Belt along the southern coast has been seismogenic during the Holocene (Goedhart. 2007) and the eastern sector in particular could produce large future earthquakes, as noted previously (Hill, 1975; Goedhart, 2007). Dingle (1980) drew an analogy between the geometry and submarine setting of the Agulhas Slump and the Storrega Slump off Norway. The latter, with a displaced volume of only ~3500 km^3 produced a tsunami with a runup exceeding 20 m (see section 3.3.1). The ~20, 000 km^3 displacement of the Agulhas Slump may likewise have generated a significant tsunami, even if slumping was not entirely instantaneous. Given the evidence for major seismic activity, allied with the low relief coastal plain and several populated centres, the southern coast represents a region of notable tsunami threat from submarine slumping.

As noted above, along the east coast the high rates of terrigenous sediment input and steepness of the sheered margin increases the predisposition for mass sediment mobilisation (Dingle, 1977; Hartnady, 2005). The southern sector around Port Elizabeth where the C-B-S fault merges with the Algulhas-Falkland fracture zone (Goedhart, 2007) may be a focus of higher seismicity than indicated in Figure 1. The coastal strip from Buffalo City to Port St.Johns (Wild Coast) was reported to be at high risk of slump-generated tsunamigenesis (Hartnady, 2002; 2005), possibly exacerbated by the offshore seismicity southeast of the Mzimvubu River (Fig. 1). The seismic zones south and north of Durban may likewise constitute areas of higher risk in view of the prominent regions of slumped areas (Fig. 1). The Tugela Cone may also be susceptible in view of the proximity of seismicity. The east coast represents a region of notable tsunami threat from submarine slumping in view of: the evidence for: extensive late Cenozoic (25 Ma-present) slumping; modern seismic activity; steepness of the sheered margin; high sedimentation rates; intermittent low relief coastal plain allowing large inland runups; and several densely populated centres.

4.3.4. Slump generated tsunami or meteotsunami?

Historical evidence for tsunami that may have been induced by offshore slumping along the South African coast is sparse. However, as pointed out previously this record is brief and small or localised events may have escaped notice.

A ‘tsunami’ centring on the west coast town of Dwarskersbos ~170 km north of Cape Town in the early hours of 26th August 1969, was reported in local South African newspapers, including *The Argus*. *Die Burger* (2005) provided a summary of eyewitness accounts of this event. The wave spilled over the ~2 m high beach ridge separating dwellings from the sea (Fig. 3), flooding houses and moving objects as large as motor vehicles. Eyewitness estimates of the tsunami amplitude was ~6 m, but this is probably an exaggeration. However, the reported runup which is less subjective and could be measured after the event was appreciable at ~100 m.

Figure 3. *Dwarskersbos on the west coast (see Figure 1 for location), scene of a possible tsunami in 1969. Gravelly each ridge is 2-3 m in height-view looking northwards.*

On 20/21 August 2008, a lengthy series of surges were observed by seemingly reliable witnesses in the harbours and estuaries of the west coast as reported in local newspapers such as the *Cape Times* and *Die Son* and summarised in SAWS (2008). The sea drew down well below MLW and then surged up again, each time rising well above MHW and in this aspect the event seemed similar to a tsunami. At Lamberts Bay, whirlpools were observed in the harbour and boats touched bottom, breaking anchor chains in some instances. A vehicle was swept away near the mouth of Berg River and at Sandy Point Harbour on the western side of St Helena Bay waterside buildings were flooded. At Hout Bay just south of Cape Town, the cruise launch *Circe* was reported to have been 'sucked out' of the mouth of the bay.

Tide gauge data from Walvis Bay in the north to Table Bay (Cape Town) in the south and at East London on the southeast coast were obtained from which the residual values of expected/measured tidal data are shown in (Figs 4 and 5). The most intense oscillations began in the earlier morning, ending around noon. Walvis Bay, situated furthest north showed little effect, but further south at Luderitz anomalies are evident, especially in the afternoon of 21/08/08. The earliest (before noon) and largest amplitude waves occurred at Port Nolloth. The waves varied in amplitude between 0.5 and 1.5m and the period from 60-15 minutes, and depending on location (Figs 4 and 5; SAWS, 2008); ~900 km coastline was affected. Data from east of Cape Point showed little or no effect and at East London on the southeast coast no anomalies can be seen.

An investigation of contemporaneous tide gauge records for the 1969 event at the Hydrographic Office at Silvermine, Cape Town also revealed aberrant tidal patterns from various sites along the sane stretch of the west coast (from Cape Town to Luderitz in Namibia, N. Flint, pers. com.). Thus the approximate magnitude and location of the 2008 event mirrors the Dwarskersbos 'tsunami' of 1969. For both the 1969 and 2008 events, no reports of large tsunami from remote sources could be found that may have produced a teletsunami along the west coast of southern Africa (USGS, 2008). Large conventional waves are known from the west coast, although the sea was reportedly calm at the time of both the 1969 and 2008 events. These considerations open the possibility that these events were localised tsunami, possibly triggered by an offshore sediment slump.

An alternative explanation of the west coast events is that they may represent atmospherically generated tsunami ('meteotsunami'). Atmospheric gravity waves exist by virtue of the stable density stratification of the atmosphere under gravity (Vibilic et al. 2006). Disturbances of a balanced state can result in excitation of atmospheric gravity waves with a variety of spatial and temporal scales. Gravity waves can transport energy and momentum from one region of the atmosphere to another and can initiate and modulate convection and subsequent hydrological processes. Gravity waves in the atmosphere can induce long wavelength oceanic oscillations, which when coastally trapped are referred to as 'edge waves' (Beer, 2007).

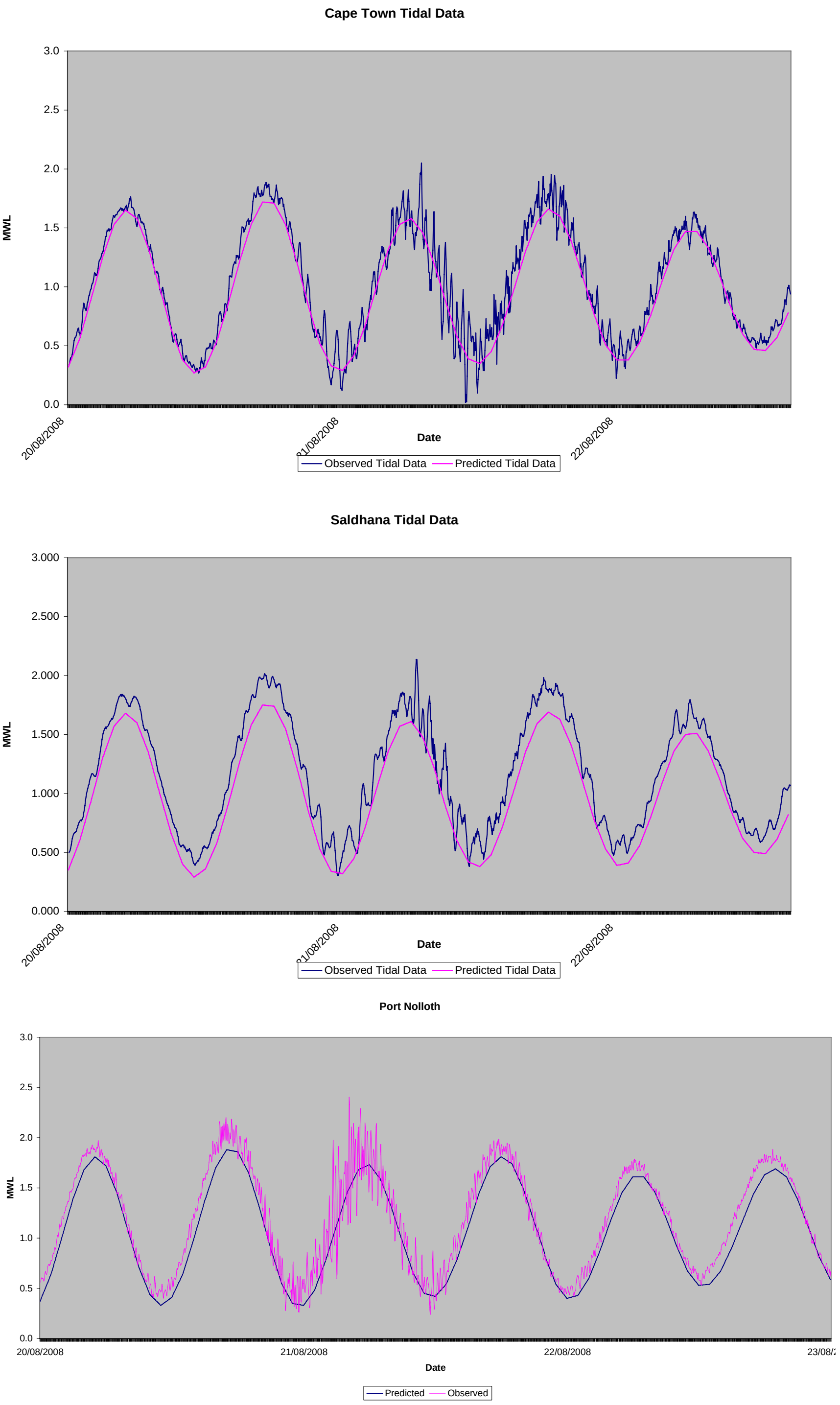

Figure 4. *Tide gauge records for Cape Town, Saldanha and Port Nolloth. All show marked anomalies over the same tidal cycle with lesser anomalies in adjacent cycles. Records from South African Hydrographic Office.*

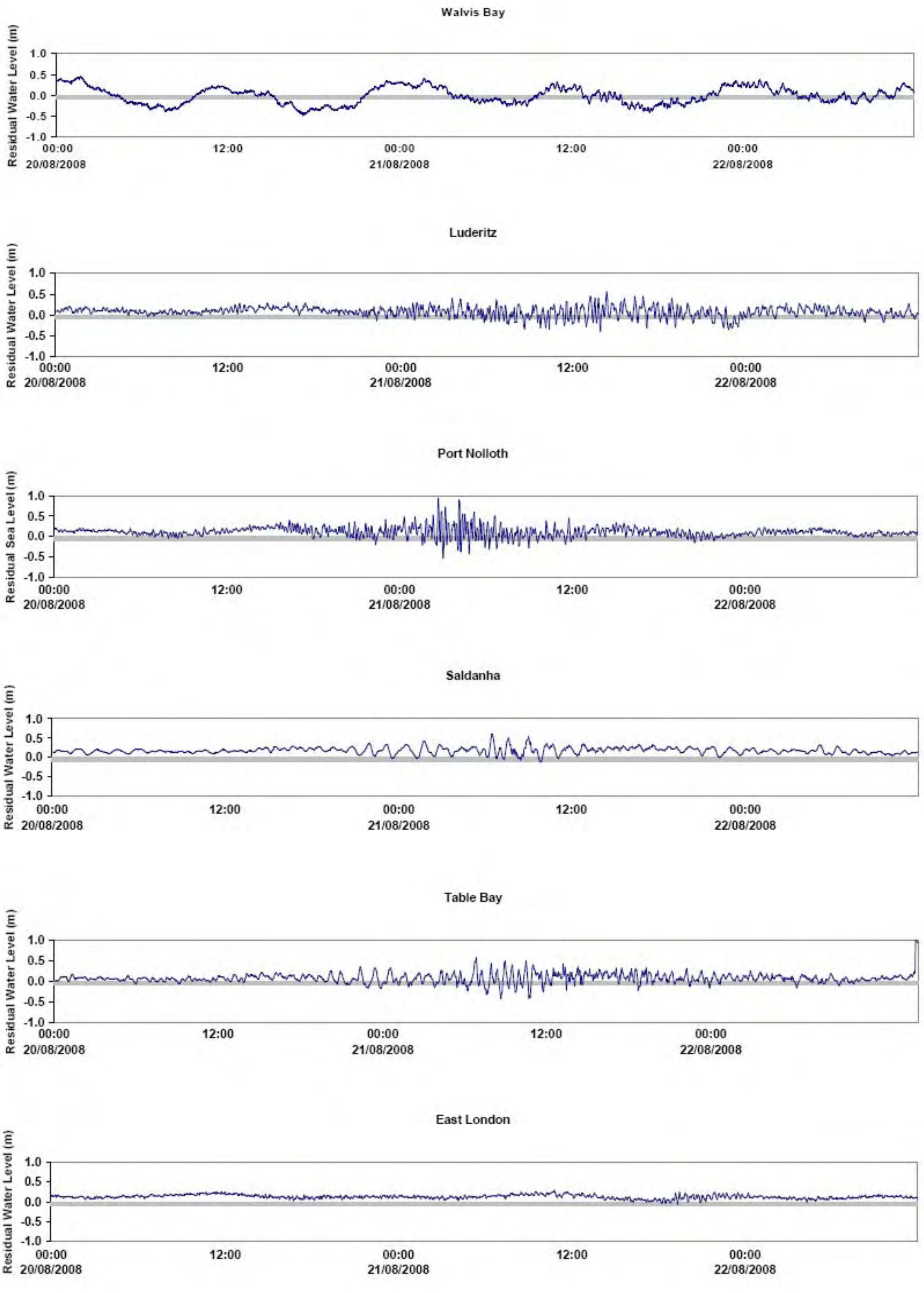

Figure 5. *The residual values of expected/measured tidal data from the west coast.*

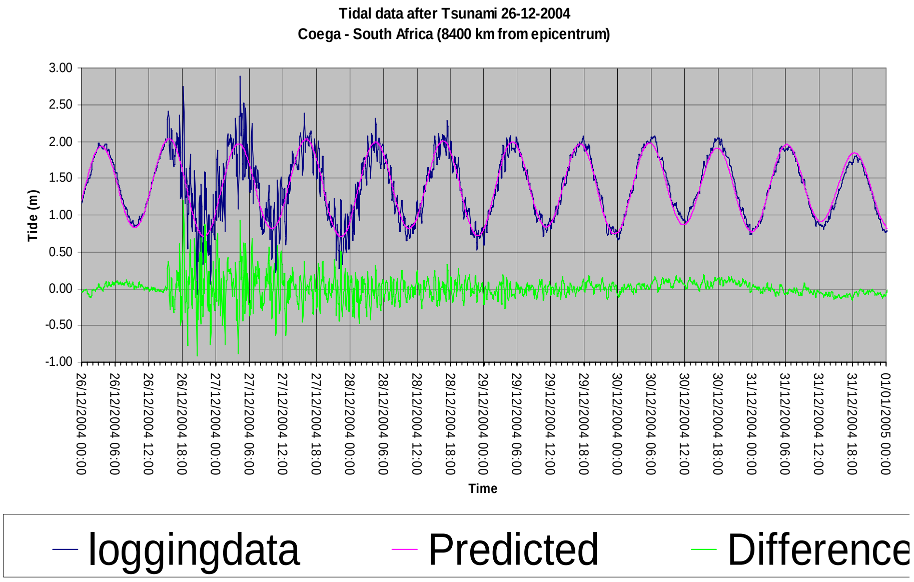

Figure 6. *Tide gauge records for Coega Harbour on the southeast coast for the 2004 Sumatran seismogenic tsunami. Note the similarity in pattern, amplitude and duration of the event in relation to the 2008 west coast tsunami.*

Meteotsunami may be modified and amplified by local topography, and can affect the coast in the same destructive manner as ‘ordinary’ tsunami waves, e.g. the magnitude 4 tsunami on the Sieberg-Ambrasey intensity scale estimated for the Middle Adriatic (Vibilic et al., 2006). There are several global localities where hazardous meteotsunamis occur regularly and have been given local names: ‘rissaga’ in the Balearic Islands, ‘marubbio’ in Sicily, ‘milghuba’ in Malta, and ‘abiki’ in Nagasaki Bay, Japan. Note that these mainly refer to relatively restricted marine environments rather than the open ocean.

Because of the cloud formations associated with them, atmospheric gravity waves may show up in satellite imagery as linear features (Fig. 6). Such features have previously been sighted in satellite imagery off the west coast of Africa (SAWS, 2008). Owing to the notable cloud cover, it was not possible to determine whether atmospheric gravity waves It is also noteworthy that rapid oscillations in air pressure were recorded at all west coast

SAWS stations from the late afternoon on August 20th (e.g. Fig. 7), through until the following morning. The observation that both the 1969 and 2008 events fell within the month of August is a further suggestion of metorological control.

Meteotsunami can also produce patterns in tide gauge records closely analogous to conventional tsunami, with multiple waves impinging on the coast for a number of hours. In accord with their long wavelength, they may cause a drawdown in the sea level followed by a surge, again analogous to conventional tsunami and reported by eyewitnesses at Lamberts Bay and other west coast localities (SAWS, 2008). Tide gauge records for Coega (southeast coast) for the 2004 Sumatran tsunami (Fig. 7) show a striking similarity in pattern, amplitude and duration of the event with the 2008 event (Figs 4 and 5).

Port Nolloth experienced the largest amplitude waves and the arrival time was earlier than the sites to the south. If the assumption of a point source was made, this suggests that the source was in the general region off Port Nolloth. However, it could also be contended that the atmospheric gravity waves manifested more strongly in this area and generated a more intense oceanographic response. In the view of the present author, the coincidence of atmospheric anomalies off the west coast coinciding with the onset of the August 20/21 event is compelling evidence of a meteogenic origin.

Anecdotal evidence exists of tsunamigenesis by a marine slump off Port St. Johns. A newspaper article read by Dr J. R. V. Reddering of the Council for Geoscience in 19xxx reported that a fisherman observed an instantaneous depression in the sea surface about X km offshore and a wave propagating outward from the depression. A large, unstable mud delta has developed off the Mzimvubu River mouth at Port St. Johnsref, lending some credence to this report.

There is therefore some (albeit tenuous) evidence for recent tsunami possibly caused by offshore slumping along the South African coast. The tsunamigenenic capacity of palaeoslumps on the scale of those on the Agulhas Bank and elsewhere on the shelf is clearly apparent by analogy with Holocene events. Ongoing seismicity, both on- and offshore could trigger further events representing a significant but as yet unquantified threat to the southern African coast.

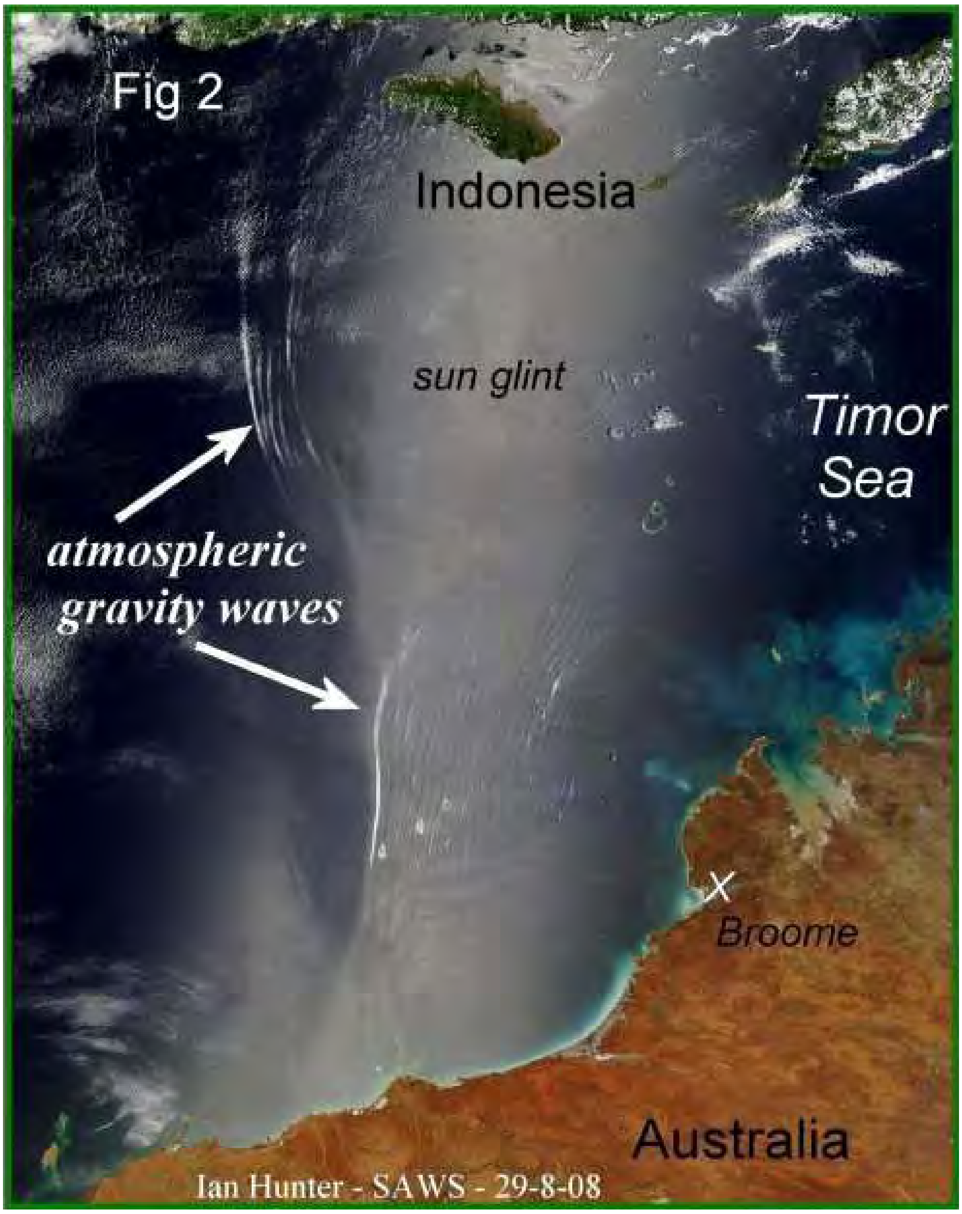

Figure 7. *An example of atmospheric gravity waves enhanced by sunglint conditions (when sunlight is reflected off a calm sea surface directly into the satellite sensor - in this case the MODIS sensor on NASA's Aqua satellite). Taken from SAWS (2008).*

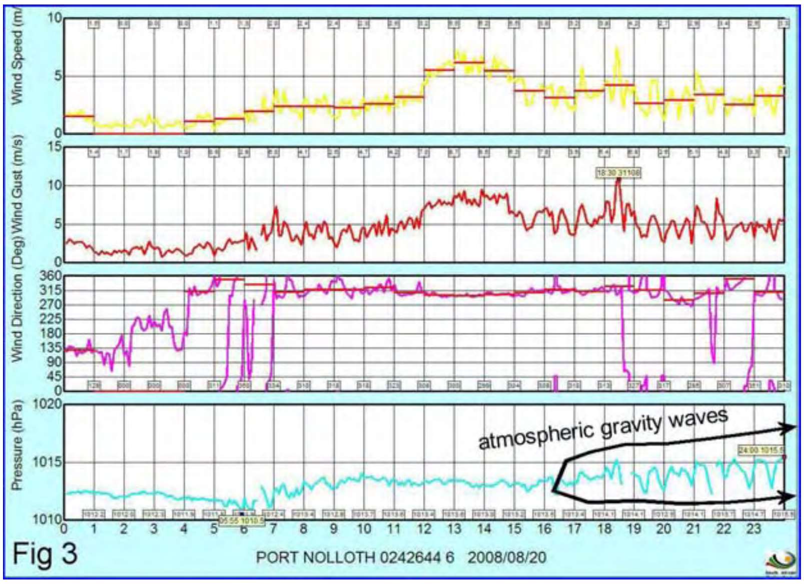

Figure 8*. Five minute interval data from SAWS's automatic weather station at Port Nolloth. Note the appearance of the relatively large oscillations in air pressure at ~ 5pm on the 20th August. These rapid changes in air pressure were recorded at all the west coast SAWS's, through until the following morning. Taken from SAWS (2008).*

4.4 Volcanic activity

Catastrophic explosive tsunamigenic volcanism is well documented in historical times such as Thera in the Aegean and Krakatoa in the Indian Ocean (e.g. Verbeek, 1984). Krakatau caused the first recorded global tsunami and ships as distant as South Africa were rocked by the waves (Pelinovsky et al., 2005).

Volcanic edifice mass failures and associated submarine landslides have the potential of generating destructive local waves in confined bodies of water and also in the open ocean (e.g. Ward and Day, 2001; Pararas-Carayannis, 2004). Modelling has suggested that flank collapse on Las Palma in the Canary Islands off North Africa could generate local waves with heights of 900-500 m and transoceanic tsunami with wave heights exceeding 20 m at localities as distant as Florida USA and the north coast of South America. According to Hartnady (2005), the islands Karthala and Reunion off the southern African east coast represents the most imminent threat of tsunamigenic volcanism/edifice collapse to South Africa, whereas Marion Island fills this role in the southern Indian Ocean (Fig. 2).

Reunion is highly active at the present time, evinced by the major eruption of 2004. Flank instability is evident around the Piton De La Fournaise volcano which shows extensive erosion, subsidence and an arcuate coastline suggestive of subsea slope failure (Pararas-Carayannis, 2004). Numerous potentially tsunamigenic flank failures and landslides that occurred during the Pleistocene and Holocene have been mapped on the seafloor (Oehler et al., 2007)

Marion Island, South Africa's only historically active volcano, lies south of the Indian Ocean Ridge, about 1700 km from Port Elizabeth (Fig. 2). The Island comprises coalesced basaltic shield volcanoes with basaltic and trachybasaltic lavas predominating. The highest peak reaches 1230 m with about 150 cinder cones forming subsidiary peaks. Whereas the earliest dated eruptions took place about 450,000 years ago, much of the island is covered by Holocene lava flows. The first historical eruption was in 1980 and produced explosive activity and lava flows from a 5 km-long fissure (Verwoerd and Langenegger, 1967; Verwoerd et al.,1981).

4.5 Terrestrial landslides and rockfalls

This section refers to non-volcanogenic terrestrial landslides and rockfalls. The largest modern wave ever recorded occurred at Lutuya Bay, southeast Alaska in 1956 (Miller, 1960). An Mw 8.2 earthquake caused a massive slab of rock to collapse into the bay, giving rise to a wave with a run-up of over 500 m. This event presented poignant evidence of the threat posed by terrestrial landslides and rockfalls into restricted environments such as marine embayments. In the Cape Town environs and southern coasts of South Africa, the highly fractured and jointed quartzitic strata of the Palaeozoic Cape Supergroup form lofty and steep (near vertical) coastal cliffs on the seaward aspect, but with gentler slopes on the landward side (Figs 9 and 10). Relatively fresh scars on cliff faces illustrate large rockfalls in the recent past. At localities such as the town of Hout Bay situated in a marine embayment, potential large rockfalls from the 330 m high sheer cliffs of The Sentinel pose a significant threat to the low-lying areas in the densely populated areas fringing the bay (Fig. 10). Quartzite blocks as large as 13x8x3 m litter the northern entrance to the bay.

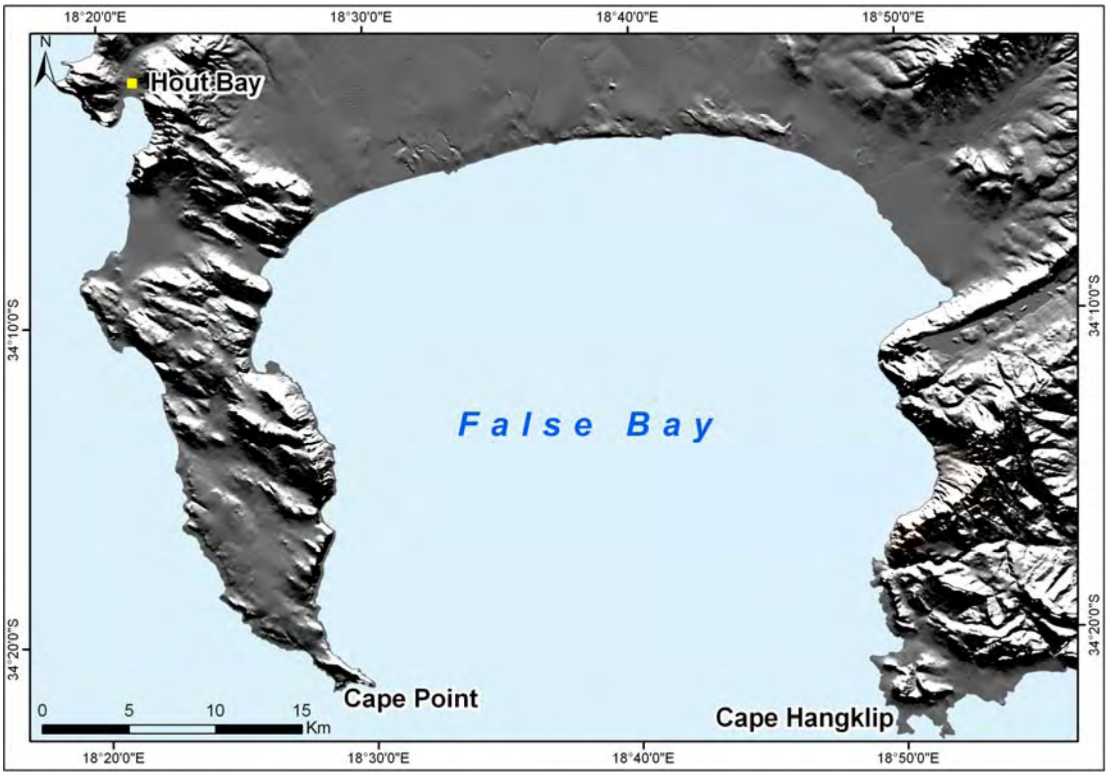

Figure 9. *DEM showing the disposition of steep hillslopes comprising highly fractured and jointed Palaeozoic quartzites, possible sources of tsunamigenic rockfalls. The town of Hout Bay is considered to be at greatest risk.*

Figure 10. *Precipitous cliffs comprising highly fractured and jointed Palaeozoic quartzites at the entrance to Hout Bay, posing a threat of tsunamigenic rockfalls to the town itself, with some dwellings and infrastructure at only 1.5 m asl.*

The large town of Knysna on the South Coast is clustered around the Knysna River estuary. Tertiary (65-1.8 Ma) to Quaternary (1.8 Ma-present) dune systems flanking the estuary range to ~250 m in height. Satellite imagery and aerial photos show evidence of massive landslides within these aeolian deposits. A large landslide about 1.3 km in diameter which deposited an estimated 75 million m^3 of sediment into the estuary is evident on the western side of the estuary at Brenton On Sea (Fig. 11). The age of the event is uncertain, but a later Holocene age is suggested by a platform at 2.5-2 m asl eroded along the distal margin of the landslide, probably recording the Mid-Holocene high sea level widely reported along the South African coast (Miller et al., 1998). The landslide still partly obstructs an estuarine channel, underpinning a young age for the feature. Further landslides of this scale in this area could have serious consequences as residential areas such as Dassen Island are situated as low as 3m asl.

Figure 11. *Major late Holocene landslide into the estuary of the Knysna River from hills comprising unstable coastal aeolianites. A repeat of an event of this order of magnitude would result in inundations of low-lying densely populated areas of the Knysna itself.*

5. Tsunami Prediction and warning time

Since seismicity on global or local scales is not predictable with any precision, it follows that tsunami generated directly or indirectly from earthquakes are not generally amenable to long term prediction either. Tsunami generated from remote submarine seismicity have predictable travel times based on known propagation velocities. Thus the arrival/warning time of known high potential sites such as the Sumatra/Anadaman subduction zone and South Sandwich Island Arc can readily be calculated and indeed this has been successfully done by computer modelling in the instance of the 2006 (Hartnady and Okal, In press).

Salomon et al. (2007) also modelled large magnitude onshore earthquakes in the northern Mediterranean region which showed that within five minutes of a strong earthquake, offshore slumps would produce a 4 to 6 m run-up that may inundate part of the Syrian, Lebanese, and Israeli coasts. The warning time for tsunami generated by local offshore slumps would be generally dependant on the width of the continental shelf at any point along the coastline. Thus along the west southern coast where the continental shelf is relatively wide, warning times would be notably longer than the east coast where the Agulhas/Falkland transform has greatly attenuated the shelf width (Fig. 2). The warning time at any point along the coast could be readily calculated from the known propagation rate of slump generated tsunami and the shelf width. The effects of the more detailed local topography of the shelf would also have to be taken account of. Satellite monitoring of oceanic wave patterns appears to be the only possible source of early warning in this instance.

The effects of tsunami generated by local landslides/rockfalls into restricted embayments would manifest quasi-contemporaneously with the event and warning time would effectively be zero. As noted in section 4.1, no cosmic impacts are currently anticipated in the foreseeable future. Even should ongoing monitoring alter this situation, the cosmic impact time and location could be calculated with some precision, as demonstrated with the Shoemaker-Levy comet impact on Jupiter in July 1994 Benner and McKinnon (1994). Possible tsunami generated from a marine impact could also be modelled.

6. Mitigation/adaptation

Short of civil engineering interventions, there seems to be little that can be done in terms of mitigation/adaptation for existing coastal infrastructure in the event of a tsunami. Such interventions would generally be of an *ad hoc* character and would depend on the situation and nature of the contruction and the modelled maximum tsunami amplitude for that region. For planned coastal infrastructure, both civil engineering modifications and location of the planned structure in terms of its elevation above sea level and distance inland are possible mitigative/adaptative actions. Again the steps taken would depend on the modelled maximum tsunami amplitude/runup for the region in question.

7. Summary and Recommendations

- This report provides a qualitative account of possible tsunamgenic sources that could threaten the South African coastline. To adequately assess the risk, a quantitative assessment of each source category is required.
- Offshore slump generated tsunami are considered the largest unknown risk factor. Holocene and recent historical records provide graphic evidence of their destructive capability on regional scales. Further research including all available stratigraphic/sedimentological/geomorphological data should be undertaken to better define the risk.
- Meteotsunami (edge waves) may well have been responsible for the 1969 and 2008 tsunami events along the southern African west coast. In depth research into the global frequency, locality and magnitude of meteotsunami should be undertaken to further quantify the risk. In particular, the atmospheric conditions along the west coast prior to the 1969 event should be compared with those of its 2008 counterpart.
- Worst case scenarios need to be defined. For instance, the potential impacts of the coincidence of maximum storm waves, storm surge, astronomical tides and meteotsunami should be modeled.
- Because of the relatively short history of tsunami records along the South African coast, the database should be extended by conducting an investigation of palaeotsunami in the stratigraphic record. No systematic work has yet been conducted along this coast. Areas of focus should be in the vicinity of planned nuclear facilities.

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APPENDIX E:

Data Reports on Oceanographic Measurements by Lwandle Technologies (Pty) Ltd

Note:

This appendix contains the oceanographic data reports compiled by Lwandle Technologies after each service visit. The data contained in these data reports undergoes additional quality control procedures by PRDW, including combining the data from each service visit into a unified dataset. For this reason the data contained in these data reports should not be used for design purposes and only the quality controlled unified data described in the main report should be used.

LWANDLE TECHNOLOGIES (PTY) LTD

LWANDLE MOBILISATION REPORT

KOEBERG – CURRENT, WAVE, TEMPERATURE AND BIOFOULING MEASUREMENTS

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

27 February 2008

Job No: LT-JOB-50

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1. PROJECT SUMMARY

Lwandle Technologies (Lwandle) have been contracted by Prestedge Retief Dresner Wijnberg (PRDW) to collect oceanographic data as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites: Koeberg, Bantamsklip and Thyspunt. Measurements of current, wave, water level, temperature and biofouling are being made at the Koeberg site in approximately 10m water depth. For these measurements the following instruments have been installed:

- CURRENTS AND WAVES: TRDI 600kHz Acoustic Doppler Current Profiler (ADCP) fitted with temperature sensor, high resolution pressure sensor and waves firmware has been deployed in a stainless steel gimballed trawl resistant bottom frame.

- TEMPERATURE AND SALINITY: One temperature & salinity (T&C) string has been deployed in 10m water depth. The string will measure temperature and salinity at two depths (near surface-3m and near bottom –8m). For these measurements a mooring fitted with 2 x RBR XR 420CT conductivity and temperature loggers has been installed. This mooring line has been attached to the ADCP frame via a polypropylene groundline

- BIOFOULING: Six (6) 50cm^2 asbestos plates have been deployed, three (3) plates at 3m depth and three (3) plates at 8m depth. At intervals of 3, 6 and 12 months one plate from each depth will be recovered, photographed, the thickness of marine growth measured and the plates then preserved in formalin for subsequent bio-analysis.

This report provides information about the deployment site, equipment used, a description of operations, problems encountered, log of events and the various completed equipment sheets.

2. SITE LOCATION

The instruments have been deployed at the location given in Table1 (positions are given in degrees and decimalised minutes) below.

Table 1 – ADCP, T&C logger and Biofouling measurement location

Position	Latitude	Longitude
ADCP, T&C and Biofouling Mooring	33°40.206 S	18°24.897 E

Figure 1 - Map of the project area. The position of the deployed instrumentation is indicated by an icon on the left.

3. INSTRUMENTATION

For the current and wave measurements, an TRD Instruments 600KHz ADCP was mounted inside a bottom mounted stainless steel frame c/w gimball assembly.

The temperature and salinity loggers have been fastened onto a 10mm galvanized steel strop via cable ties, hose clamps and duct tape, with five 11" floats (total upward buoyancy of 35.5 kgs) to keep the line vertical. This mooring line was connected to the ADCP frame by means of a 15m long 10mm polypropylene rope.

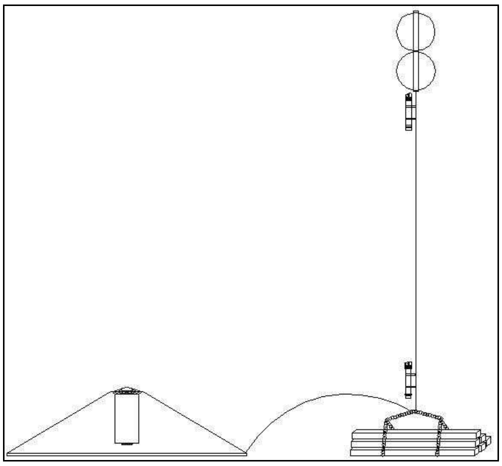


Figure 2- Temperature & salinity mooring attached to ADCP frame

The biofouling mooring line consisted of three (3) 11" floats (total upward buoyancy of 22.5 kgs), below this a three meter section of 12mm ski rope to which three (3) asbestos plates have been attached using cable ties, a 1m galvanized steel strop below this to which a 1.6m length of ski rope was attached, which held the bottom three plates.

An Edgetech acoustic release has been connected to the bottom of mooring line, so that the biofouling mooring may be released separately from the ADCP and T&C mooring line.

Figure 3 **– Biofouling mooring and anchor weights**

The detailed set-up for the ADCP and T&C loggers can be found in the deployment sheets in Section 6, and these are summarised in Table 2 and Table 3 below.

Table 2 – Instrument configuration for the ADCP

Parameter	**Configuration**
ADCP model	600KHz WH ADCP
ADCP serial number	10120
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.35 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

Table 3- Instrument configuration for T&C Mooring Line

Parameter	**Configuration**
XR 420 Temperature and Conductivity	s/n 12999 (3m) and s/n 12997 (8m)
Sampling and Averaging	10min sampling and 1min averaging

Table 4 – Instrument configuration for Biofouling Mooring Line

Parameter	Configuration
Biofouling Plates	3 plates (50cmx50cm) at 3m and 3 plates (50cmx50cm) at 8m
Edgetech Acoustic Release	s/n 32385 release code 642102

4. DESCRIPTION OF OPERATIONS

Lwandle engineers were mobilised from Cape Town to Koeberg for the deployment of the equipment. A summary of the sequence of events associated with the mobilisation trip is given in Table 5 below.

Table 5 – Sequence of events

Date	Description
16 January 2008 - 08h30	Lwandle's engineers and Paul Hanekom (skipper) all congregated at UCT and left together for Koeberg.
10h15	The engineers and skipper arrived at Koeberg and proceeded to access point 1 (ACP1). They then contacted Erinay from Eskom to arrange entrance to slipway. At the slipway the ADCP frame and mooring lines were set up and put on board the vessel.
11h20	The vessel departed from Koeberg harbour and headed towards the mooring position.
11h55	The engineers marked the position of site with floatline. The T&C Mooring line was lowered next to the floatline, using the 17m groundline (attached to ADCP on deck) in 10.5m of water (33°40.205 S and 18°24.898 E). The 2 x RBR sensors were attached to the groundline. The first RBR sensor (s/n 1999) will sit at the surface (3m) and the second RBR sensor (s/n 1997) will sit at 8m.
12h14	The ADCP frame was lowered down just seaward of T&C mooring (33°40.206 S and 18°24.897 E). The chain weights for the ADCP frame were then lowered. Afterwards the divers entered the water to attach weights to the frame and spread out the groundline (bottom time 28mins). Divers also attached extra 11" floats to T&C mooring line (diving time 11mins).
13h45	The biofouling mooring (33°40.203 S and 18°24 .897 E) was deployed. The vessel then headed back to harbour. The engineers phoned security to alert them that they were proceeding into Koeberg harbour.

Figure 4 **– ADCP frame with 600KHz instrument.**

5. PROBLEMS ENCOUNTERED AND MITIGATION MEASURES

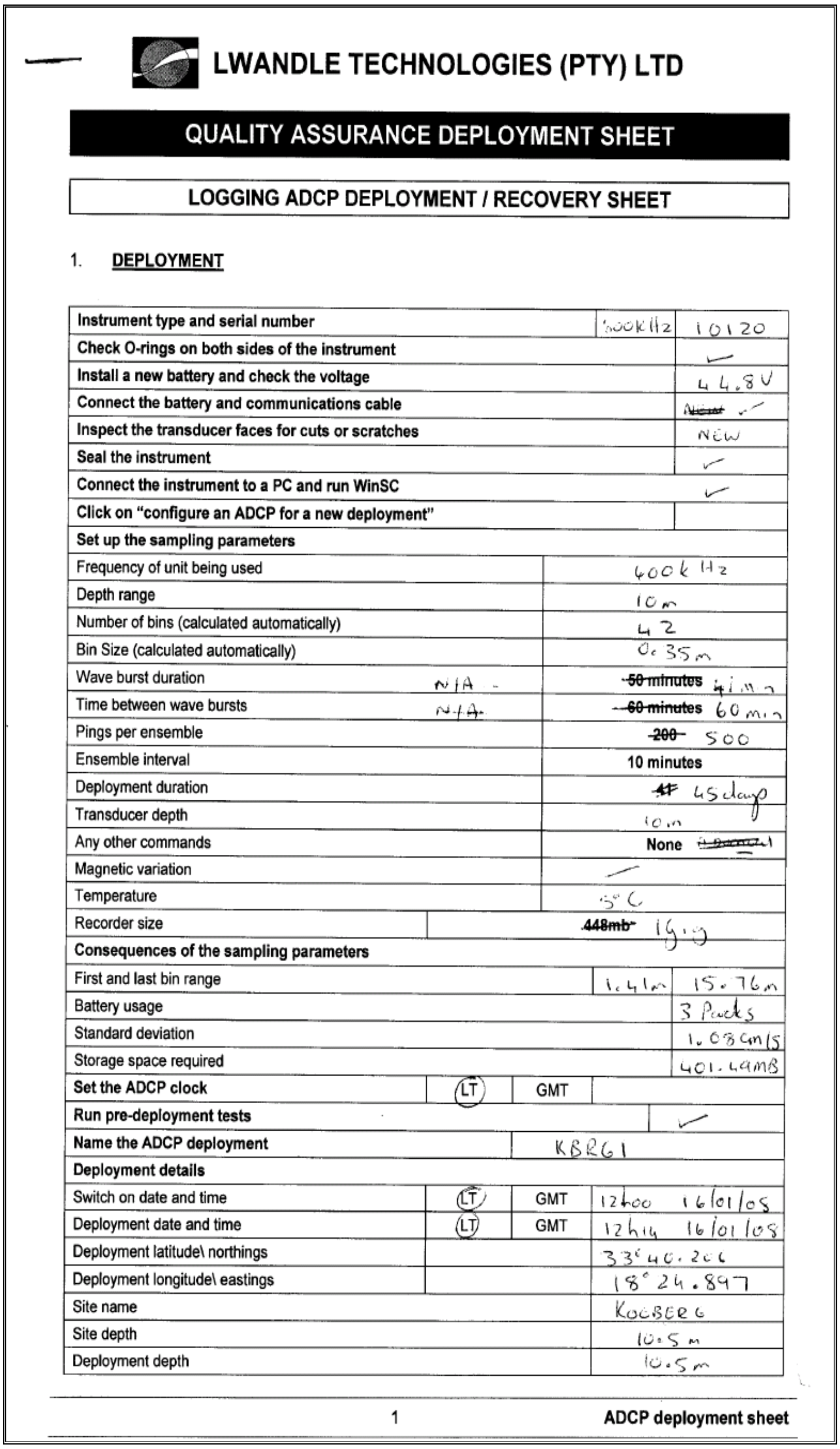
A list of problems experienced and mitigation measures taken are provided in Table 6.

Table 6 – Problems and mitigation measures

Problem	**Mitigation measure(s)**
Access to the Koeberg facility was difficult and very time consuming.	Organize special permit for easy access to slipway.

6. VARIOUS INSTRUMENT SHEETS

6.1 ADCP DEPLOYMENT SHEET



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

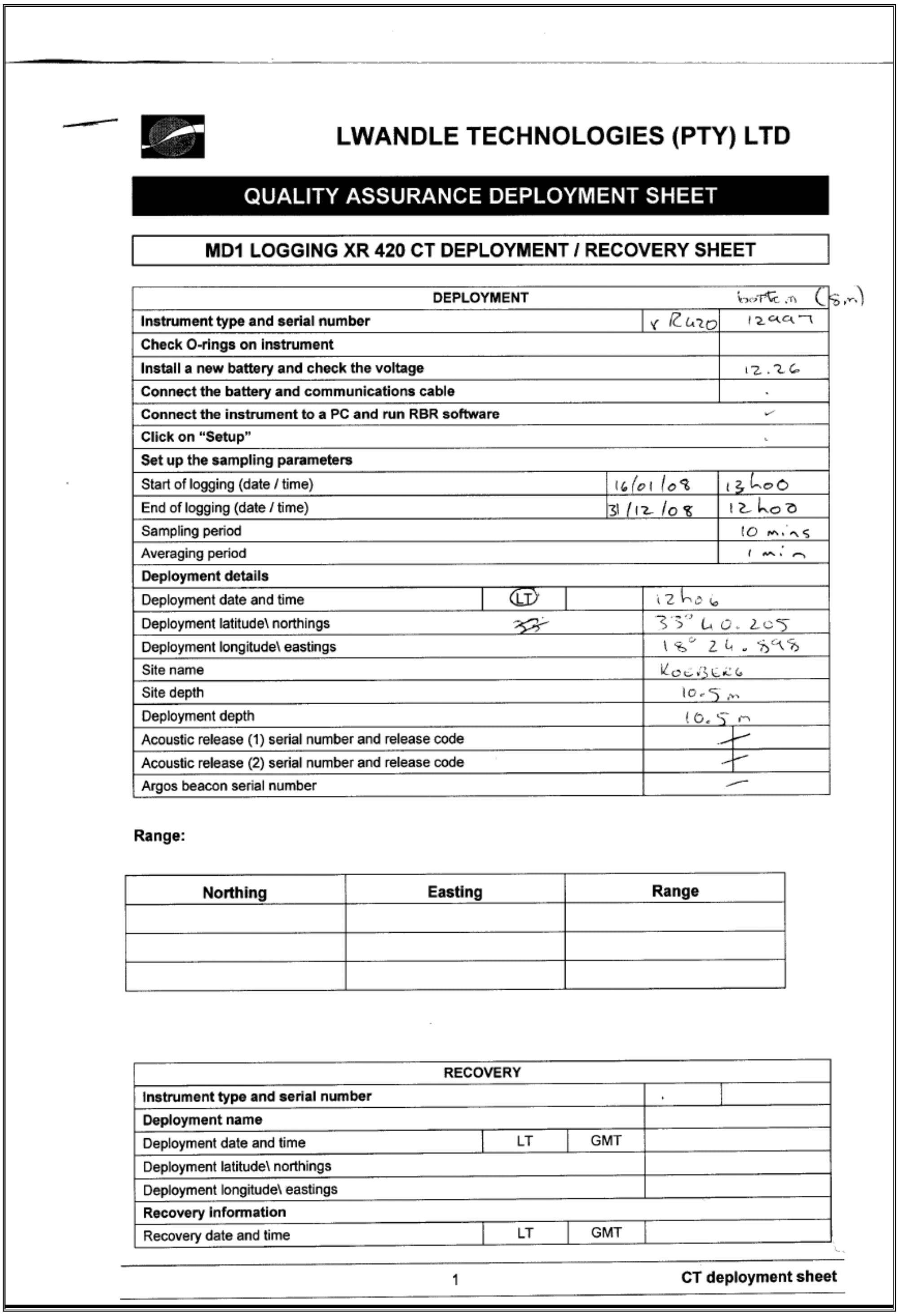
LOGGING ADCP DEPLOYMENT / RECOVERY SHEET

1. **DEPLOYMENT**

Instrument type and serial number		600kHz	10120
Check O-rings on both sides of the instrument			✓
Install a new battery and check the voltage			44.8V
Connect the battery and communications cable			~~New~~ ✓
Inspect the transducer faces for cuts or scratches			NEW
Seal the instrument			✓
Connect the instrument to a PC and run WinSC			✓
Click on "configure an ADCP for a new deployment"			
Set up the sampling parameters			
Frequency of unit being used			600kHz
Depth range			10m
Number of bins (calculated automatically)			42
Bin Size (calculated automatically)			0.35m
Wave burst duration	N/A -		~~50 minutes~~ 41 min
Time between wave bursts	N/A		~~60 minutes~~ 60 min
Pings per ensemble			~~200~~ 500
Ensemble interval			10 minutes
Deployment duration			~~41~~ 45 days
Transducer depth			10m
Any other commands			None ~~[illegible]~~
Magnetic variation			—
Temperature			5°C
Recorder size			~~448mb~~ 1gig
Consequences of the sampling parameters			
First and last bin range		1.41m	15.76m
Battery usage			3 Packs
Standard deviation			1.08cm/s
Storage space required			401.49MB
Set the ADCP clock	[✓ LT]	GMT	
Run pre-deployment tests			✓
Name the ADCP deployment			KBRG1
Deployment details			
Switch on date and time	[✓ LT]	GMT	12h00 16/01/05
Deployment date and time	[✓ LT]	GMT	12h14 16/01/08
Deployment latitude\ northings			33°40.206
Deployment longitude\ eastings			18°24.897
Site name			KOEBERG
Site depth			10.5 m
Deployment depth			10.5m

1 ADCP deployment sheet

6.2 RBR LOGGER DEPLOYMENT SHEETS



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

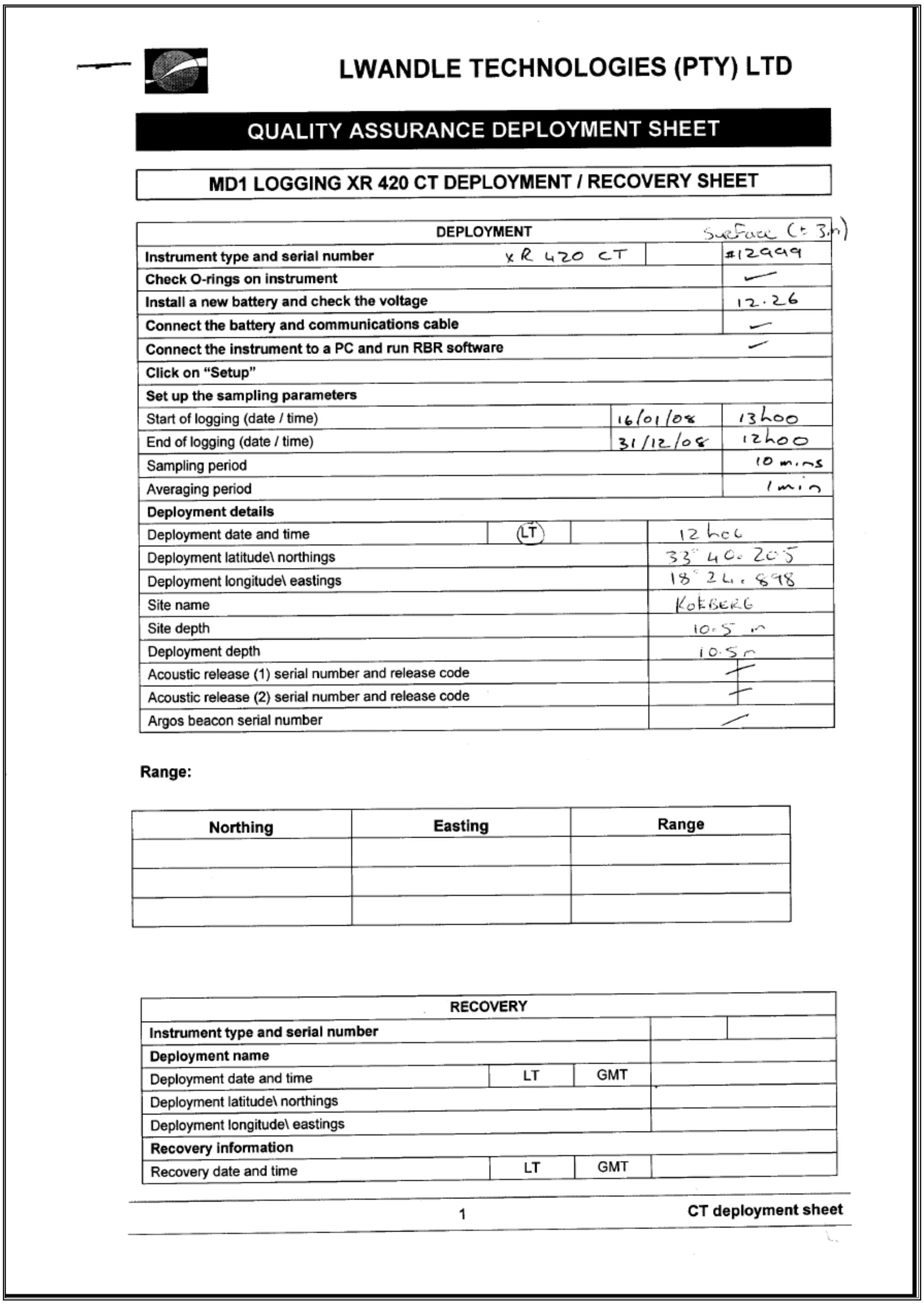
DEPLOYMENT		bottom (8m)
Instrument type and serial number	xR420	12997
Check O-rings on instrument		
Install a new battery and check the voltage		12.26
Connect the battery and communications cable		
Connect the instrument to a PC and run RBR software		✓
Click on "Setup"		
Set up the sampling parameters		
Start of logging (date / time)	16/01/08	13h00
End of logging (date / time)	31/12/08	12h00
Sampling period		10 mins
Averaging period		1 min
Deployment details		
Deployment date and time	[✓ LT]	12h06
Deployment latitude\ northings	~~33~~	33° 40.205
Deployment longitude\ eastings		18° 24.898
Site name		KOEBERG
Site depth		10.5m
Deployment depth		10.5m
Acoustic release (1) serial number and release code		–
Acoustic release (2) serial number and release code		–
Argos beacon serial number		–

Range:

Northing	Easting	Range

RECOVERY			
Instrument type and serial number			
Deployment name			
Deployment date and time	LT	GMT	
Deployment latitude\ northings			
Deployment longitude\ eastings			
Recovery information			
Recovery date and time	LT	GMT	

1 **CT deployment sheet**



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

DEPLOYMENT			Surface (± 3m)
Instrument type and serial number	XR 420 CT		#12999
Check O-rings on instrument			✓
Install a new battery and check the voltage			12.26
Connect the battery and communications cable			✓
Connect the instrument to a PC and run RBR software			✓
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		16/01/08	13h00
End of logging (date / time)		31/12/08	12h00
Sampling period			10 mins
Averaging period			1 min
Deployment details			
Deployment date and time	[✓ LT]		12h06
Deployment latitude\ northings			33° 40.205
Deployment longitude\ eastings			18° 24.898
Site name			KOEBERG
Site depth			10.5 m
Deployment depth			10.5m
Acoustic release (1) serial number and release code			-
Acoustic release (2) serial number and release code			-
Argos beacon serial number			-

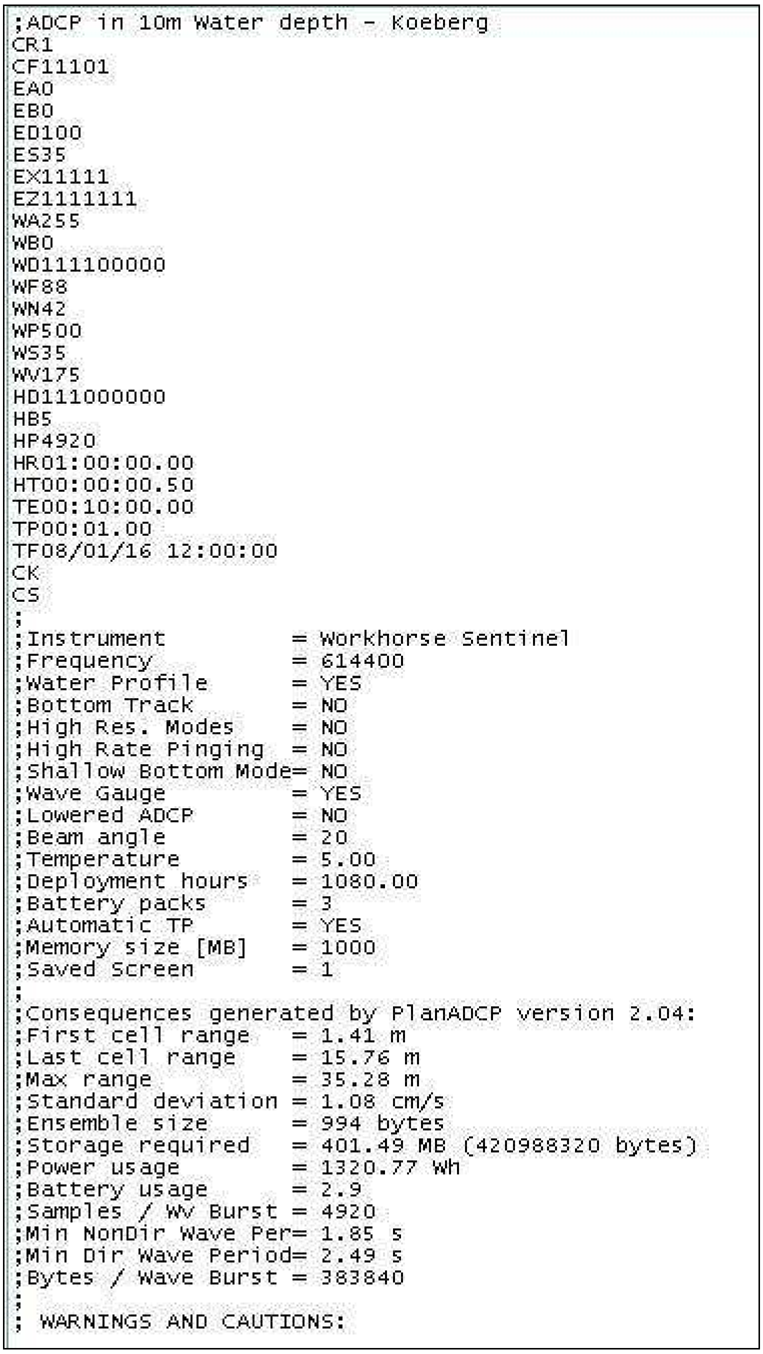
Range:

Northing	Easting	Range

RECOVERY			
Instrument type and serial number			
Deployment name			
Deployment date and time	LT	GMT	
Deployment latitude\ northings			
Deployment longitude\ eastings			
Recovery information			
Recovery date and time	LT	GMT	

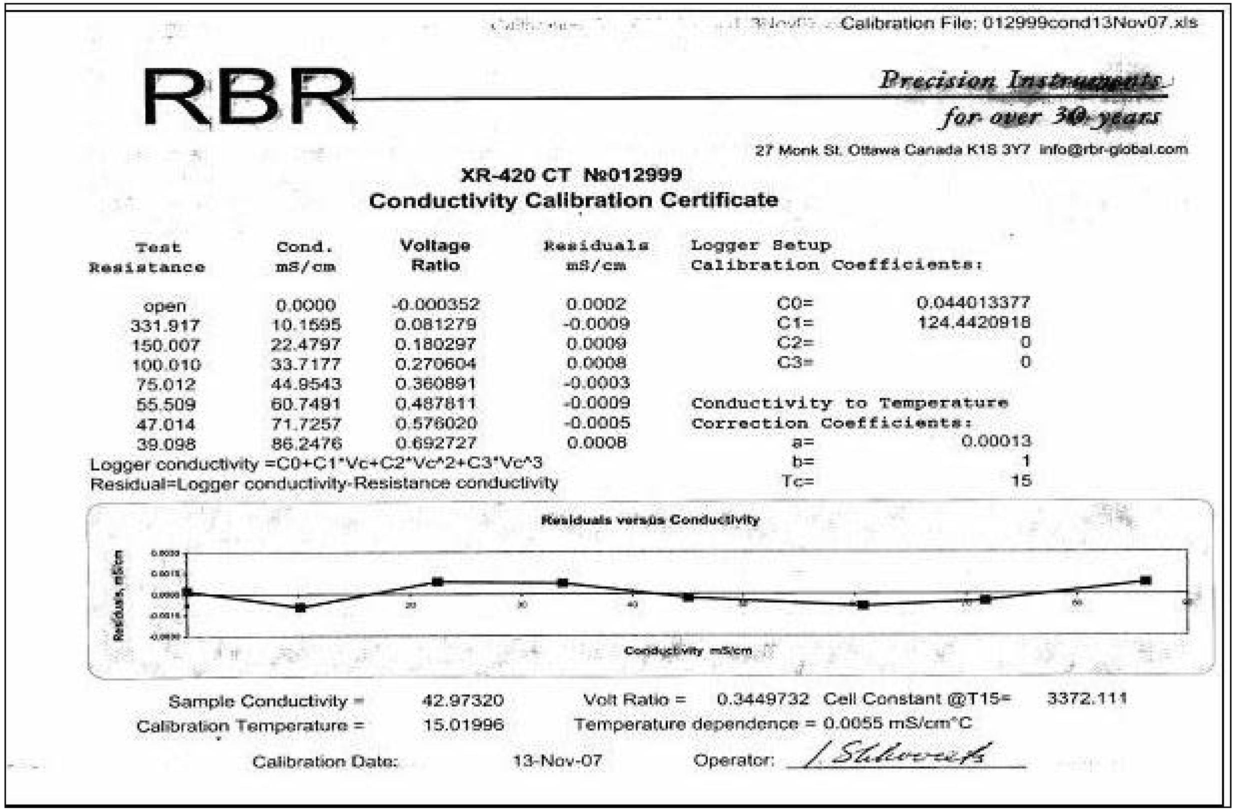
1 **CT deployment sheet**

6.3 ADCP CONFIGURATION FILE



```
;ADCP in 10m Water depth - Koeberg
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:01.00
TF08/01/16 12:00:00
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 1080.00
;Battery packs       = 3
;Automatic TP        = YES
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 401.49 MB (420988320 bytes)
;Power usage         = 1320.77 Wh
;Battery usage       = 2.9
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
;
; WARNINGS AND CAUTIONS:
```

6.4 RBR AND T&C CALIBRATION CERTIFICATES



Calibration File: 012999cond13Nov07.xls

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012999
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000352	0.0002
331.917	10.1595	0.081279	-0.0009
150.007	22.4797	0.180297	0.0009
100.010	33.7177	0.270604	0.0008
75.012	44.9543	0.360891	-0.0003
55.509	60.7491	0.487811	-0.0009
47.014	71.7257	0.576020	-0.0005
39.098	86.2476	0.692727	0.0008

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.044013377
C1= 124.4420918
C2= 0
C3= 0

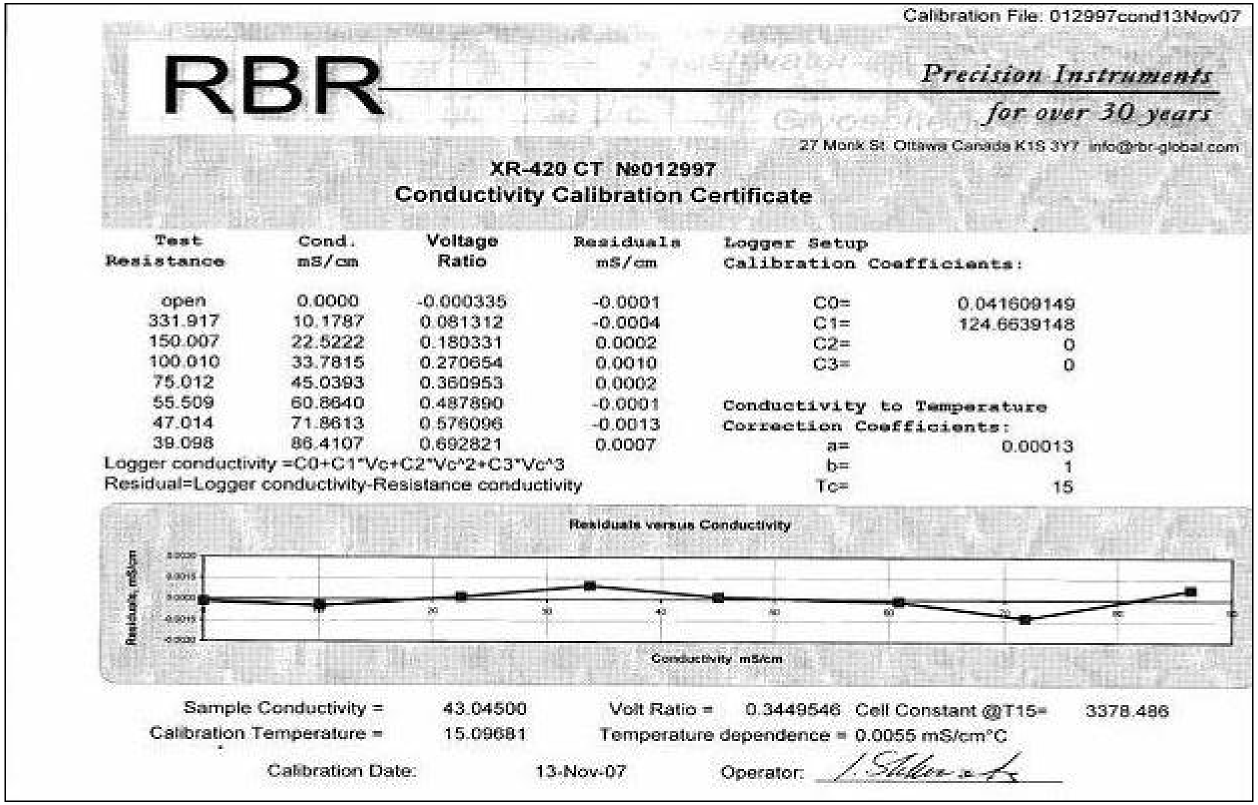
Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 42.97320
Volt Ratio = 0.3449732
Cell Constant @T15= 3372.111
Calibration Temperature = 15.01996
Temperature dependence = 0.0055 mS/cm°C

Calibration Date: 13-Nov-07
Operator: / Shlovetzk



Calibration File: 012997cond13Nov07

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012997
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000335	-0.0001
331.917	10.1787	0.081312	-0.0004
150.007	22.5222	0.180331	0.0002
100.010	33.7815	0.270654	0.0010
75.012	45.0393	0.360953	0.0002
55.509	60.8640	0.487890	-0.0001
47.014	71.8613	0.576096	-0.0013
39.098	86.4107	0.692821	0.0007

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.041609149
C1= 124.6639148
C2= 0
C3= 0

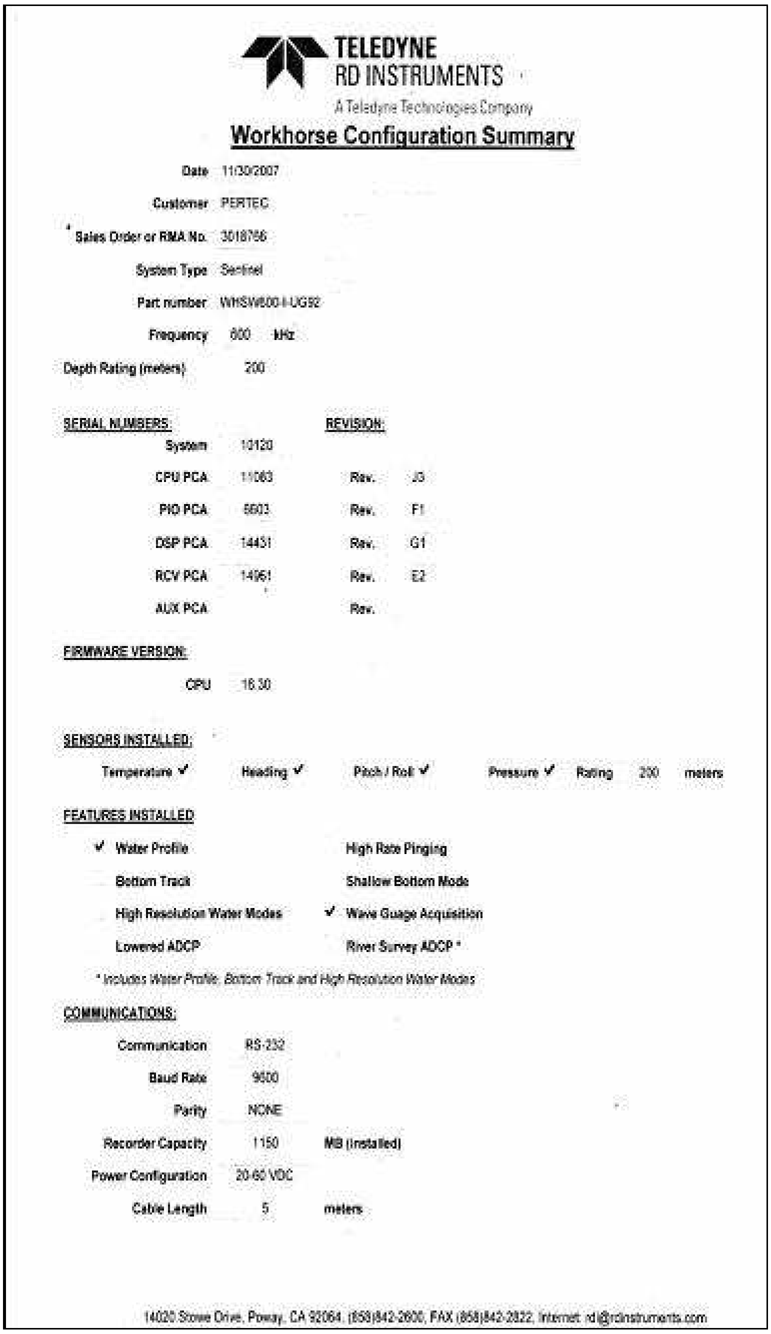
Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Sample Conductivity = 43.04500
Calibration Temperature = 15.09681
Volt Ratio = 0.3449546
Cell Constant @T15= 3378.486
Temperature dependence = 0.0055 mS/cm°C

Calibration Date: 13-Nov-07
Operator:

6.5 TRDI ADCP CALIBRATION CERTIFICATE



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 11/30/2007

Customer PERTEC

* **Sales Order or RMA No.** 3018766

System Type Sentinel

Part number WHSW600-I-UG92

Frequency 600 **kHz**

Depth Rating (meters) 200

SERIAL NUMBERS:		**REVISION:**	
System	10120		
CPU PCA	11063	**Rev.**	J3
PIO PCA	6603	**Rev.**	F1
DSP PCA	14431	**Rev.**	G1
RCV PCA	14961	**Rev.**	E2
AUX PCA		**Rev.**	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ **Heading** ✓ **Pitch / Roll** ✓ **Pressure** ✓ **Rating** 200 **meters**

FEATURES INSTALLED

✓ **Water Profile**	**High Rate Pinging**
Bottom Track	**Shallow Bottom Mode**
High Resolution Water Modes	✓ **Wave Guage Acquisition**
Lowered ADCP	**River Survey ADCP** *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232

Baud Rate 9600

Parity NONE

Recorder Capacity 1150 **MB (installed)**

Power Configuration 20-60 VDC

Cable Length 5 **meters**

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT ONE

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

12 June 2008

Job No: LT-JOB-50

LWANDLE TECHNOLOGIES (PTY) LTD

Directors: C.P. Matthysen, M. Majodina, B.J. Spolander

1st floor Gabriel Place, 1 Gabriel Road, Plumstead, 7800, South Africa

Co Reg. No. 2003/015524/07

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 1 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-8.9	99.17	0.7223	0.0951	0.1020	0.0414	3.07
-8.6	99.02	0.7589	0.0984	0.1056	0.0436	3.23
-8.2	98.83	0.7593	0.1012	0.1085	0.0465	3.32
-7.9	98.35	0.7900	0.1041	0.1118	0.0498	3.32
-7.5	98.23	0.8042	0.1057	0.1147	0.0529	2.50
-7.2	98.18	0.8178	0.1081	0.1175	0.0561	1.17
-6.8	98.17	0.7995	0.1105	0.1200	0.0593	359.48
-6.5	98.13	0.8187	0.1129	0.1224	0.0624	357.78
-6.1	98.08	0.8412	0.1153	0.1252	0.0661	356.02
-5.8	98.06	0.8075	0.1179	0.1274	0.0692	354.08
-5.4	98.05	0.8576	0.1209	0.1302	0.0729	352.15
-5.1	98.01	0.8416	0.1244	0.1328	0.0775	349.98
-4.7	98.01	0.8501	0.1284	0.1350	0.0818	347.86
-4.4	98.01	0.8639	0.1329	0.1375	0.0866	346.08
-4.0	98.01	0.8722	0.1378	0.1399	0.0915	344.26
-3.7	98.01	0.8733	0.1432	0.1418	0.0967	342.80
-3.3	98.00	0.9030	0.1487	0.1439	0.1018	341.60
-3.0	98.00	0.9111	0.1547	0.1463	0.1066	341.27
-2.6	98.01	0.9310	0.1611	0.1485	0.1116	341.51
-2.3	98.01	0.9336	0.1687	0.1508	0.1191	342.64
-1.9	98.00	0.9706	0.1798	0.1524	0.1264	344.82
-1.6	98.00	0.9798	0.1936	0.1564	0.1374	349.55
-1.2	88.97	0.9849	0.2023	0.1531	0.1409	352.16

Table 2 – Waves summary

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	99.69	5.12	0.39	1.34	0.54
Tp (s)	99.69	19.60	2.00	11.24	2.27

Table 3 – Water temperature and salinity summary

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100	11.27	15.6	9.28
Conductivity	100	38.38	43.22	33.64
Salinity (psu)	100	34.09	35.03	29.23

2. INTRODUCTION

2.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period January 16th 2008 - March 11th 2008 (Period 1) as well as sediment, water and grab samples collected during Service Visit 1 (March 10th – 13th 2008).

2.2 EQUIPMENT LIST

Lwandle provided the equipment as listed in Table 4 for the Koeberg site.

Table 4 – List of equipment provided.

Item	Operational (on site)	Spare (for whole project)
TRDI 600kHz ADCP	1	1
RBR XR420 CT logger	2	1

2.3 MEASUREMENT LOCATION

The initial deployment location of the mooring is given in Table 5 and shown in Figure 1. Table 6 – Table 8 show the locations where water samples, grab samples and beach samples were taken respectively.

Figure 1 - Map of the project area. The position of the deployed instrumentation is indicated by an icon on the left.

Table 5 – Initial deployment locations.

Location	Longitude (^oE)	Latitude (^oS)	Approx. water depth (m)
Koeberg	18° 24.897’	33° 40.206’	10

Table 6 – Locations where water samples were taken.

Station 10 Mar 2008		Latitude (^oS)	Longitude (^oE)
S1	Instrument site 2m	33° 40.206’	18° 24.897’
S2	Instrument site 4m	33° 40.206’	18° 24.897’
S3	Instrument site 6m	33° 40.206’	18° 24.897’
S4	Instrument site 8m	33° 40.206’	18° 24.897’
S5	Inshore-4m	33° 40.507’	18° 25.453’
S6	Inshore-4m	33° 40.329’	18° 25.367’
S7	Inshore-4m	33° 40.225’	18° 25.249’
S8	Inshore-4m	33° 40.074’	18° 25.155’
S9	Inshore-4m	33° 39.903’	18° 25.036’
S10	Inshore-4m	33° 39.646’	18° 24.853’
S11	Inshore-4m	33° 39.376’	18° 24.716’

Table 7 – Locations where grab samples were taken.

Station 10-11 Mar 2008	Latitude (^oS)	Longitude (^oE)
Gs1	33° 41.239’	18° 25.693’
Gs2	33° 41.320’	18° 25.396’
Gs3	33° 41.437’	18° 24.985’
Gs4	33° 40.760’	18° 25.399’
Gs5	33° 40.881’	18° 25.277’
Gs6	33° 40.990’	18° 24.800’
Gs7	33° 40.360’	18° 25.403’
Gs8	33° 40.459’	18° 24.986’
Gs9	33° 40.602’	18° 24.608’
Gs10	33° 40.117’	18° 25.301’
Gs11	33° 40.226’	18° 24.896’
Gs12	33° 40.360’	18° 24.445’
Gs13	33° 39.911’	18° 25.057’
Gs14	33° 40.042’	18° 24.785’
Gs15	33° 40.177’	18° 24.364’
Gs16	33° 39.809’	18° 24.966’
Gs17	33° 39.835’	18° 24.674’
Gs18	33° 39.967’	18° 24.256’
Gs19	33° 39.486’	18° 24.809’
Gs20	33° 39.525’	18° 24.528’

Table 8 – Locations where beach samples were taken.

13 Mar 2008	High water		Low water	
Station	**Latitude (°S)**	**Longitude (°E)**	**Latitude (°S)**	**Longitude (°E)**
S1	33° 37.505’	18° 23.785’	33° 37.516’	18° 23.768’
S2	33° 37.846’	18° 24.007’	33° 37.854’	18° 24.006’
S3	33° 38.215’	18° 24.325’	33° 38.219’	18° 24.325’
S4	33° 38.594’	18° 24.526’	33° 38.601’	18° 24.518’
S5	33° 38.927’	18° 24.842’	33° 38.936’	18° 24.825’
S6	33° 39.295’	18° 25.082’	33° 39.304’	18° 25.070’
S7	33° 39.475’	18° 25.198’	33° 39.483’	18° 25.183’
S8	33° 39.673’	18° 25.316’	33° 39.679’	18° 25.303’
S9	33° 39.868’	18° 25.402’	33° 39.869’	18° 25.384’
S10	33° 40.064’	18° 25.498’	33° 40.070’	18° 25.480’
S11	33° 40.262’	18° 25.591’	33° 40.267’	18° 25.574’
S12	33° 40.455’	18° 25.650’	33° 40.450’	18° 25.618’
S13	33° 40.862’	18° 25.909’	33° 40.867’	18° 25.897’
S14	33° 40.931’	18° 25.940’	33° 40.937’	18° 25.913’
S15	33° 41.138’	18° 26.032’	33° 41.152’	18° 25.999’
S16	33° 41.336’	18° 26.113’	33° 41.362’	18° 26.087’
S17	33° 41.760’	18° 26.314’	33° 41.775’	18° 26.272’
S18	33° 42.178’	18° 26.465’	33° 42.191’	18° 26.404’
S19	33° 42.619’	18° 26.578’	33° 42.638’	18° 26.510’
S20	33° 43.039’	18° 26.620’	33° 43.054’	18° 26.585’

3. OPERATIONS

3.1 SUMMARY OF EVENTS

A summary of events associated with the deployment of the moorings is given in Table 9. Service visit 1 was undertaken on March 10th 2008 and is detailed in Table 10.

Table 9 – Summary of events for the mobilisation of the equipment

Date	Description
16 January 2008 08h30	Lwandle’s engineers and Paul Hanekom (skipper) all congregated at UCT and left together for Koeberg.
16 January 2008 10h15	The engineers and skipper arrived at Koeberg and proceeded to access point 1 (ACP1). They then contacted Erinay from Eskom to arrange entrance to the slipway. At the slipway the ADCP frame and mooring lines were set up and put on board the vessel.
16 January 2008 11h20	The vessel departed from Koeberg harbour and headed towards the mooring position.
16 January 2008 11h55	The engineers marked the position of site with floatline. The T&C Mooring line was lowered next to the floatline, using the 17m groundline (attached to the ADCP on deck) in 10.5m of water (33°40.205 S and 18°24.898 E). The 2 RBR sensors were attached to the groundline. The first RBR sensor (s/n 1999) sits at the surface (3m) and the second RBR sensor (s/n 1997) sits at 8m.
16 January 2008 12h14	The ADCP frame was lowered down just seaward of T&C mooring (33°40.206’ S and 18°24.897’ E). The chain weights for the ADCP frame were then lowered. Afterwards the divers entered the water to attach weights to the frame and spread out the groundline (bottom time 28mins). The divers also attached extra 11” floats to T&C mooring line (diving time 11mins).
16 January 2008 13h45	The biofouling mooring (33°40.203’ S and 18°24.897’ E) was deployed. The vessel then headed back to harbour. The engineers phoned security to alert them that they were proceeding into Koeberg harbour.

Table 10 – Summary of events for Service Visit 1

Date	Description
10 March 2008 10h00	Lwandle’s engineers met up with the dive support team at Koeberg Nuclear Power Station, South Breakwater entrance.
10 March 2008 10h15	The engineers and divers loaded up the Lwandle vessel.
10 March 2008 10h30	The vessel departed from Koeberg harbour and headed towards the mooring position.

10 March 2008 10h45	The engineers marked the position of site with floatline. The divers entered the water to locate the ADCP mooring using the circular sweep search technique. The divers surfaced after 14 minutes and reported that they located the ADCP mooring and moved the marker line onto the frame. They could not get to the chain sections to remove them, due to the fact that the whole mooring was sanded over. The Lwandle engineers tried to raise the frame using the winch on the vessel, but this was deemed not safe by the Party Chief. The retrieval operations were stopped for the day, to be continued the following day, using proper underwater lifting equipment.
10 March 2008 12h20	The divers were dropped off at the harbour and the engineers loaded up the relevant sampling equipment.
10 March 2008 13h00	The engineers proceeded to the water samples sites and collected the specified 11 water samples. After this, grab samples 1 to 10 were completed.
11 March 2008 08h00	The Lwandle Engineers finished off the last 10 grab samples.
11 March 2008 09h20	The divers boarded and relevant lifting gear were loaded on the vessel.
11 March 2008 09h40	The divers descended with 2 50kg lifting bags and tried to “shuffle” the mooring out of the sand. The 2 50kg bags proved not to have enough lift. The divers then attached a 500kg lift bag to the ADCP mooring and proceeded to lift the frame out of the sand. Once the frame was free of the sand, the 4 sections of rig chain were removed, and the frame lifted to the surface using the smaller lift bags. The groundline was disconnected from the ADCP frame and fitted onto the sections of chain. The divers then proceeded to swim along the groundline and released the T&C mooring line from the anchor weights. The vessel returned to the harbour to complete the servicing on the instruments.
11 March 2008 10h15	The surface RBR unit was not communicating via the software interface and the ADCP download would have to happen using a cable, as the card format was not compatible with the download PC. It was decided to mobilize for the deployment on the following day, as the equipment would need to be returned to the office and to locate a spare RBR unit.
12 March 2008 09h00	The instruments were fitted to the frames and mooring line. An Argos satellite beacon was also fitted onto the ADCP frame.
12 March 2008 10h00	The ADCP mooring was lowered down close to the four sections of rig chain. The divers went down to re-attach the chain sections. This proved to be quite time consuming as there was quite a big swell running, causing plenty of bottom surge. The divers then pulled the T&C mooring line along the ground-rope and re-attached onto the anchor weights.
12 March 2008 12h38	The vessel returned to the harbour after a successful deployment.
13 March 2008 10h30	Lwandle engineers started their beach walk on either side of Koeberg Nuclear Power station and collected beach sediment samples at the high water and low water mark.

3.2 INSTRUMENT CONFIGURATIONS

The as deployed instrumentation configurations are given in this section and completed deployment / recovery sheets are given as an appendix (Section 7, page 40) to this report.

3.2.1 600kHz ADCP

Table 11 – Instrument configuration for the ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	10120
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.35 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

3.2.2 RBR XR420 CT LOGGER

Table 12 – Instrument configuration for T&C Mooring Line.

Parameter	Configuration
XR 420 Temperature and Conductivity	s/n 12999 (3m) and s/n 12997 (8m)
Sampling and Averaging	Sample at 1Hz for 1 minute every 10 minutes

RBR logger s/n 12999 was found faulty during the service visit and was withdrawn. The spare logger (s/n 12996) was used instead. Logger s/n 12997 was deployed at 3m (surface), and 12996 at 8m (bottom).

3.2.3 Biofouling Mooring

Table 13 – Instrument configuration for Biofouling Mooring Line.

Parameter	Configuration
Biofouling Plates	3 plates (50cmx50cm) at 3m and 3 plates (50cmx50cm) at 8m
Edgetech Acoustic Release	s/n 32385 release code 642102

3.3 RECOVER AND REDEPLOYMENT METHODOLOGY

3.3.1 T&C mooring

The T&C mooring line was deployed by lowering the array down via a rope through the anchor weights. The mooring line is recovered using divers to undo a single shackle that connects the mooring line to the anchor weights. Divers reattach the line onto the weights, after the instruments have been serviced.

3.3.2 ADCP mooring

The ADCP Frame is lowered to the bottom and moved into position by divers, who also attach chain sections that act as anchors. To retrieve the frame divers have to locate the mooring, take off the anchor chains and surface the frame using air lift bags that they attach.

Figure 2 – ADCP frame with 600KHz instrument.

3.3.3 Biofouling mooring

The biofouling mooring line was deployed by lowering the array down via a rope through the anchor weights. Divers will locate the mooring line and retrieve a surface and bottom plate from the line at the required sampling periods. Recovery of the biofouling mooring was not scheduled for the first service visit.

3.4 MALFUNCTIONS AND LESSONS LEARNT

A list of malfunctions experienced and consequent measures to be taken in future are provided in Table 14.

Table 14 – Lessons learnt and future mitigation measures

Malfunction	Future action(s)
Sand movement lifted the frame by about 0.3m during the deployment period.	Look at alternative methods of installing the equipment, e.g. concrete plinths, sand bags, water jetting piles.
Sanding over of ADCP mooring provided problems for lifting of frame.	Order lifting bags that divers can use for lifting.
RBR logger s/n 12999 was faulty.	It was replaced with the spare logger, s/n 12996

4. DATA QUALITY CONTROL

4.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

4.1.1 Current processing

- The record was truncated to exclude times pre and post deployment.
- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 1' W.
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP's pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of $0.2ms^{-1}$ was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined. These sensors were within their operating range until March 3rd 2008 (Figure 3). The data beyond the 3rd of March was observed to be doubtful. This was suspected to be due to the ADCP's battery life coming to an end.
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

4.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 1' W.
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

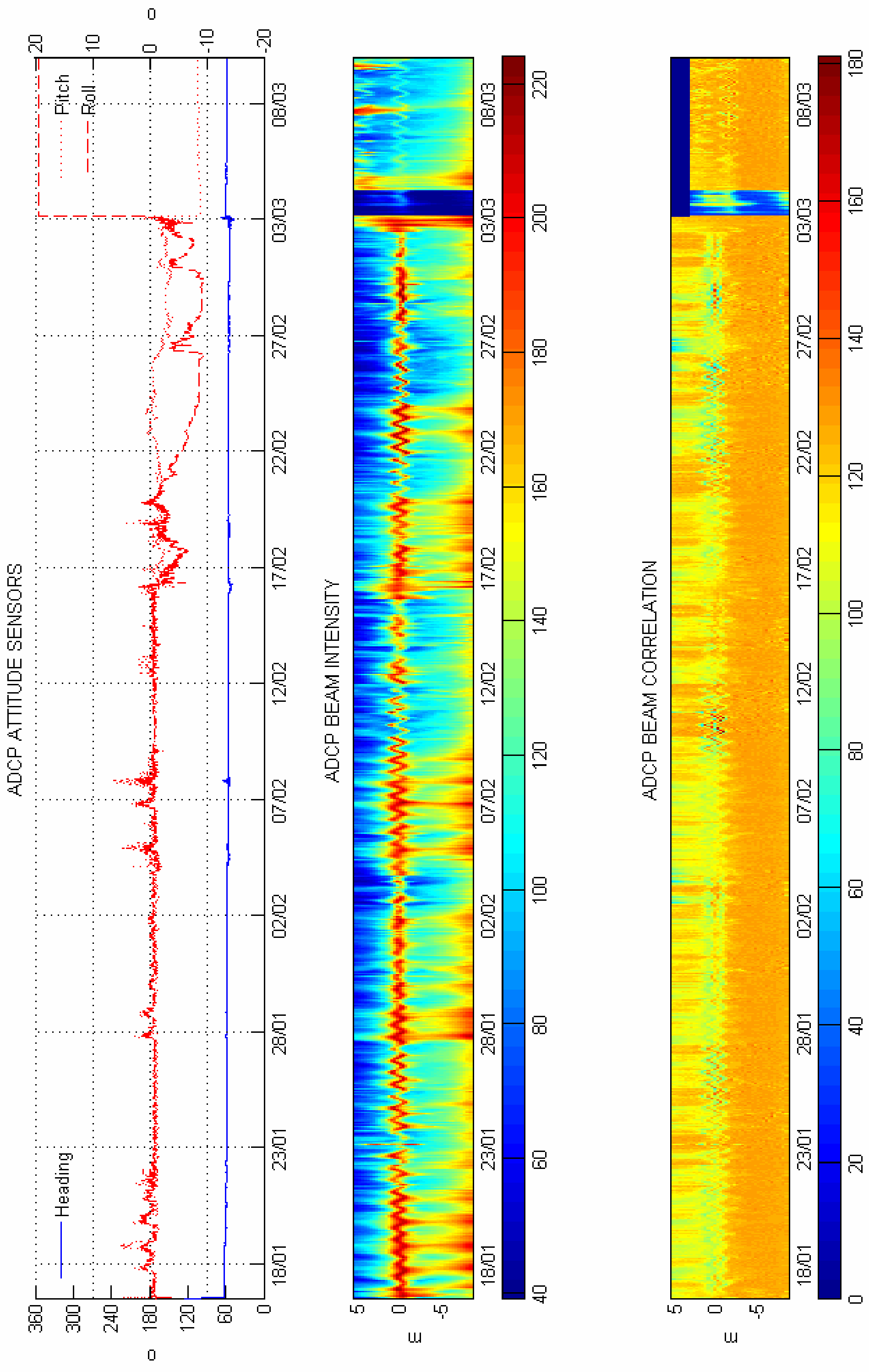


Figure 3: Quality control data from the ADCP. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

4.2 RBR-CT LOGGER

The conductivity and temperature data were exported directly from the RBR software into Matlab for further processing.

Two RBR-CT loggers were deployed at 3m and 8m depth. However, data from only one (1) logger, at 8m, were recovered successfully. The faulty logger was returned to the supplier and replaced with the spare unit.

4.2.1 Temperature and Salinity processing

- The record was truncated to exclude times pre and post deployment.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.

4.3 BIOFOULING.

The following standard procedure is followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates are measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 CaC03 chips are added.
- Sample bottles are stored upright in the dark.

Biofouling sample was not taken at Koeberg during service visit 1.

4.4 SEDIMENTS AND WATER SAMPLE.

Sediments and water sample were collected and sent to the Council for Scientific and Industrial Research (CSIR) for analysis.

5. DATA PRESENTATION

All data presented have been subject to the quality control procedures detailed in the previous section. Bad data have been excluded from all plots and calculations. However, current and wave data beyond the 3rd of March 2008 are presented for completeness purposes, despite the deviation from acceptable levels observed in the pitch and roll sensors.

All plots in this section include a stamp that details the location, depth, time period and number of observations that the plot is based upon. Wherever possible, scaling of parameters has been kept constant throughout this section to facilitate comparison between plots and stations.

5.1 ADCP

5.1.1 Current Data

5.1.1.1 Time series plot

The figures on the following pages display time series plots for depths of 8.9m, 5.1m and 1.2m, representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

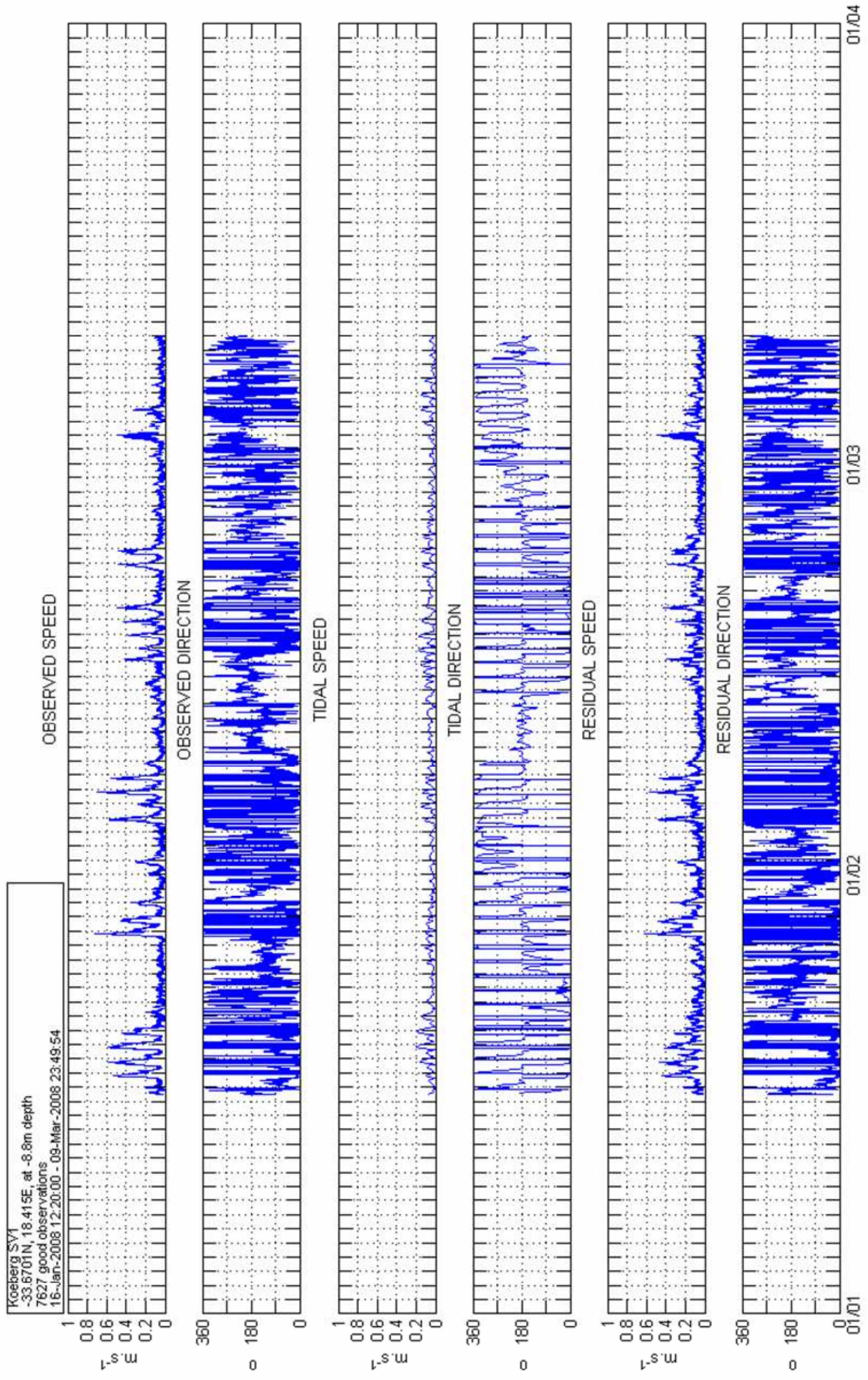


Figure 4: Time series plot of the ADCP's current data at 8.9m.

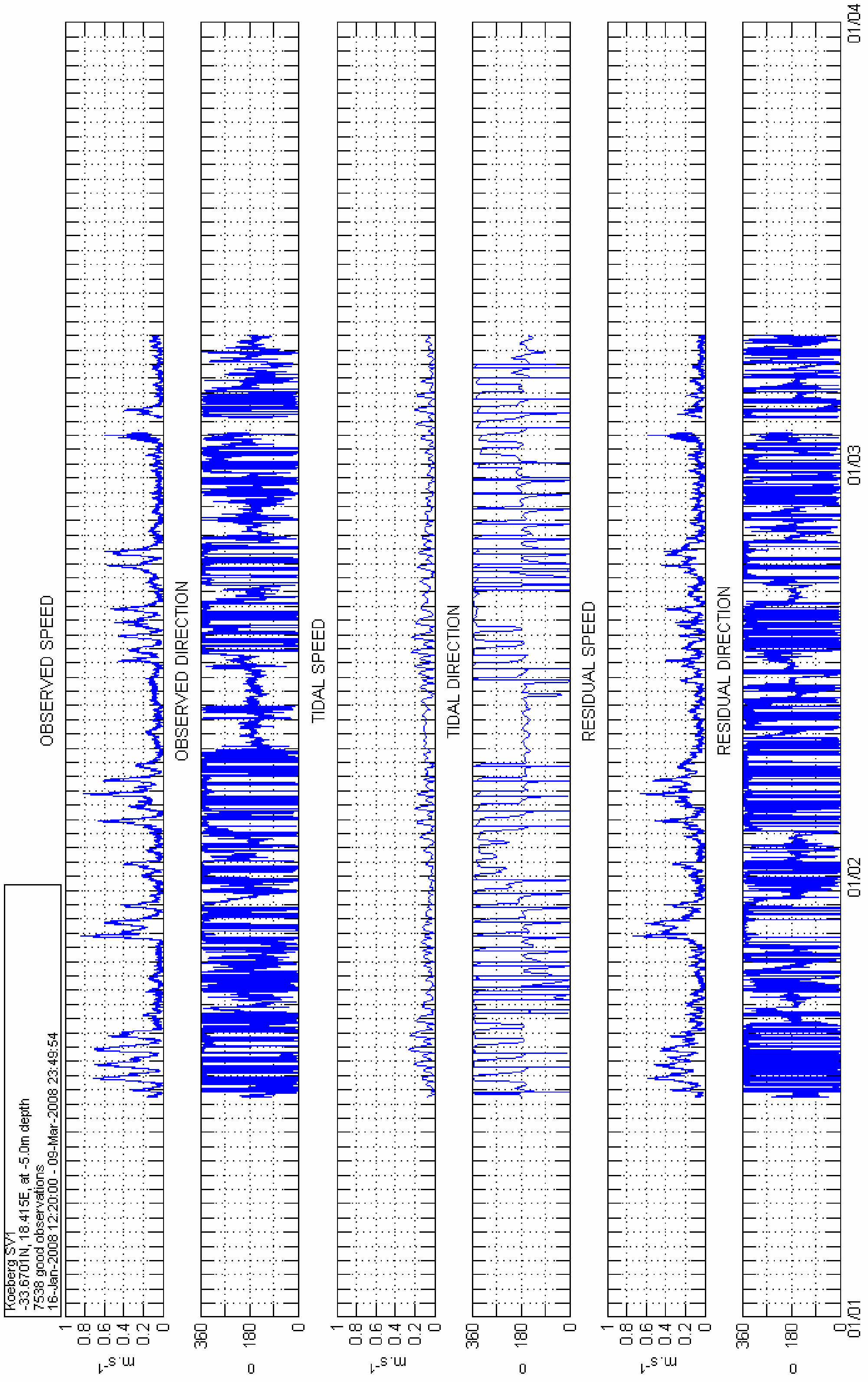


Figure 5: Time series plot of the ADCP's current data at 5.1m.

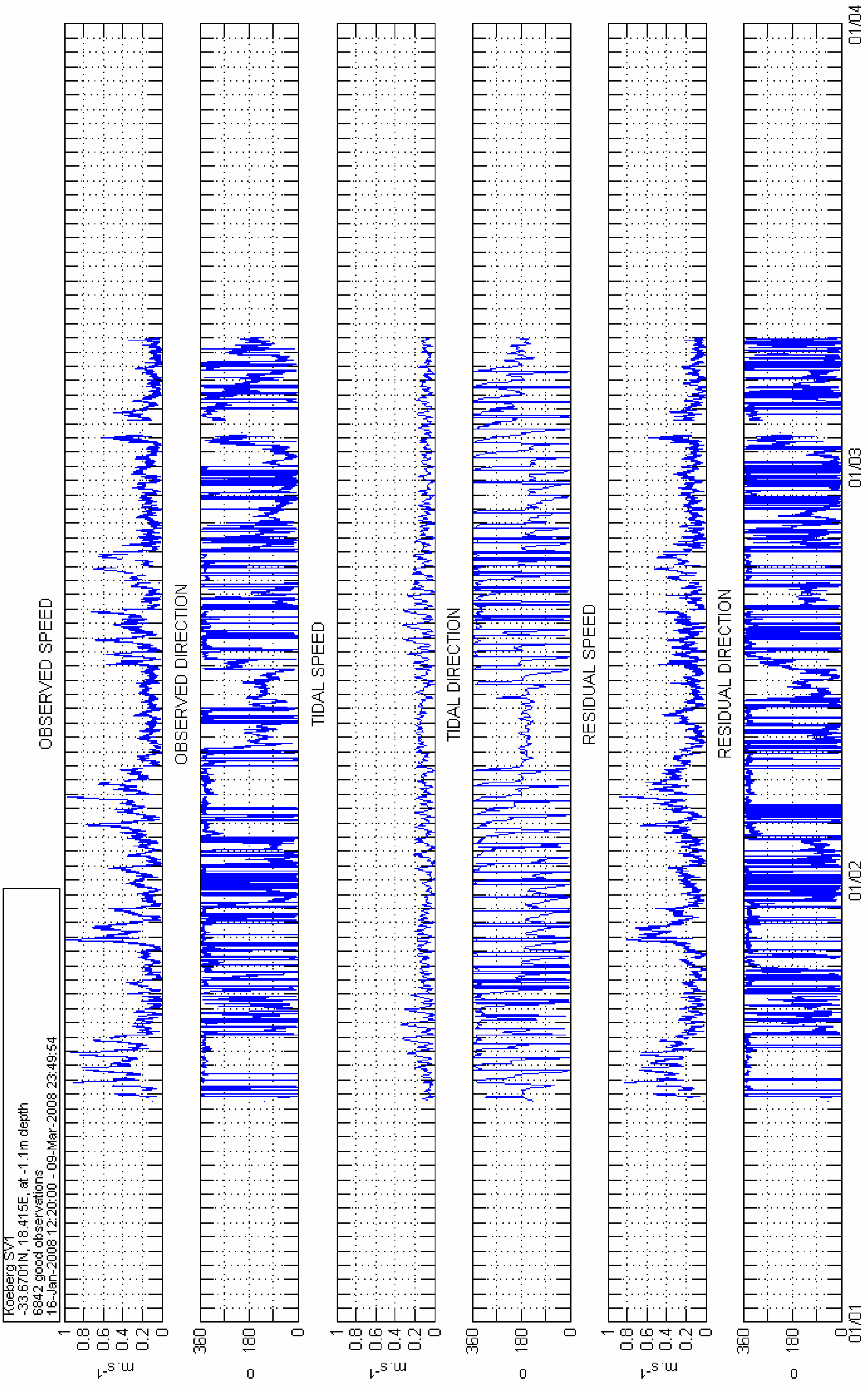


Figure 6: Time series plot of the ADCP's current data at 1.2m.

5.1.1.2 Summary plot

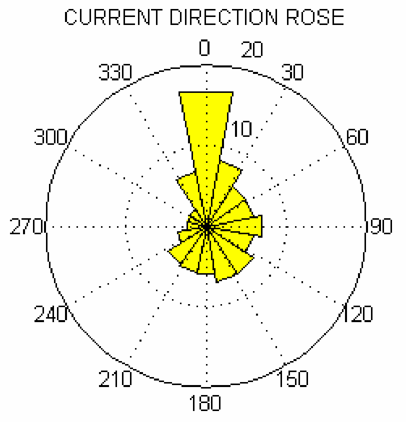
The figures on the following pages display summary plots for depths of 8.9m, 5.1m and 1.2m, representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg SV1
-33.6701N, 18.415E, at -8.8m depth
7627 good observations
16-Jan-2008 12:20:00 - 09-Mar-2008 23:49:54

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	4.12	5.31	5.44	5.87	6.98	5.98	6.99	6.52	5.11	4.82	4.52	3.08	2.20	1.99	1.95	2.94	73.83
0.1-0.2	4.65	2.49	0.60	0.14	0.04	0.01	0.18	0.52	0.90	0.96	0.84	0.39	0.17	0.30	0.33	1.49	14.04
0.2-0.3	3.58	0.43							0.01	0.05	0.18	0.07	0.04	0.05	0.14	1.17	5.73
0.3-0.4	2.32	0.08								0.07	0.10	0.08	0.04	0.04	0.03	0.66	3.41
0.4-0.5	1.55	0.01									0.03	0.05	0.01	0.01	0.05	0.34	2.06
0.5-0.6	0.62															0.16	0.77
0.6-0.7	0.08															0.07	0.14
0.7-0.8	0.01																0.01
0.8-0.9																	0.00
0.9-1																	0.00
Σ	16.93	8.33	6.04	6.02	7.01	5.99	7.17	7.04	6.03	5.90	5.68	3.67	2.46	2.40	2.50	6.82	100.00



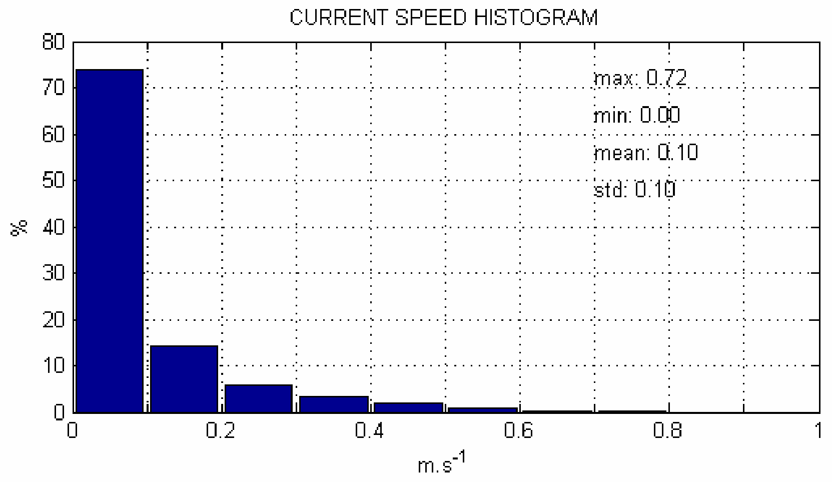
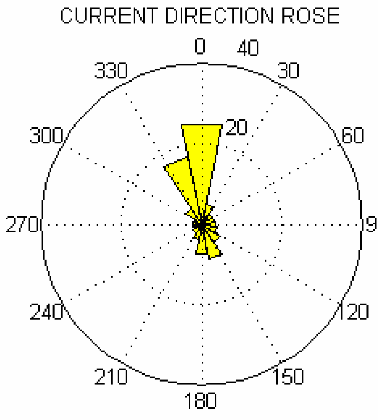


Figure 7: Summary plot of the ADCP's current data at 8.9m.

Koeberg SV1
-33.6701N, 18.415E, at -5.0m depth
7538 good observations
16-Jan-2008 12:20:00 - 09-Mar-2008 23:49:54

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	7.04	4.39	2.95	2.92	3.36	3.70	5.47	7.48	5.77	3.41	2.14	1.71	1.78	1.79	3.10	6.02	63.03
0.1-0.2	7.32	0.69	0.03	0.01	0.01	0.07	0.23	1.34	1.55	0.36	0.15	0.09	0.20	0.15	1.14	4.68	18.02
0.2-0.3	4.60	0.01						0.04	0.08	0.11	0.13	0.05	0.05	0.09	0.27	2.87	8.30
0.3-0.4	2.83								0.01	0.03	0.07	0.13	0.07	0.05	0.13	1.46	4.78
0.4-0.5	1.58									0.01	0.01	0.01	0.03	0.01	0.07	1.05	2.77
0.5-0.6	1.35											0.01				0.61	1.98
0.6-0.7	0.61															0.20	0.81
0.7-0.8	0.11															0.16	0.27
0.8-0.9	0.04															0.01	0.05
0.9-1																	0.00
Σ	25.48	5.09	2.97	2.93	3.37	3.77	5.69	8.86	7.42	3.91	2.49	2.02	2.12	2.10	4.71	17.06	100.00



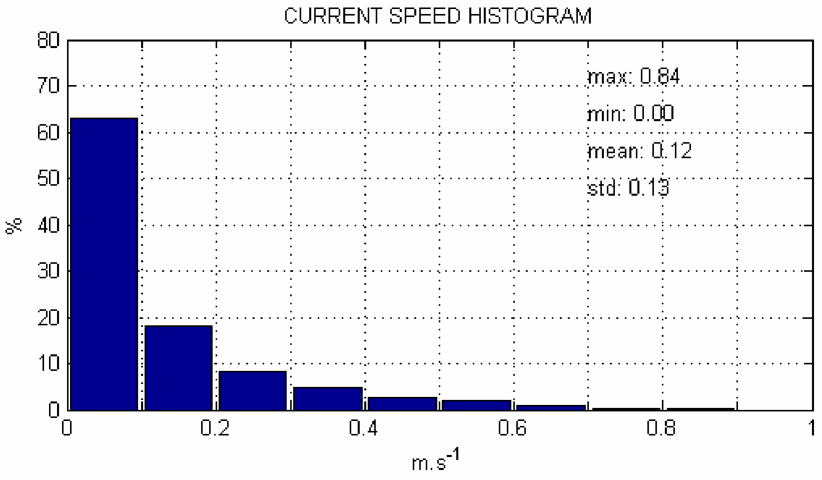
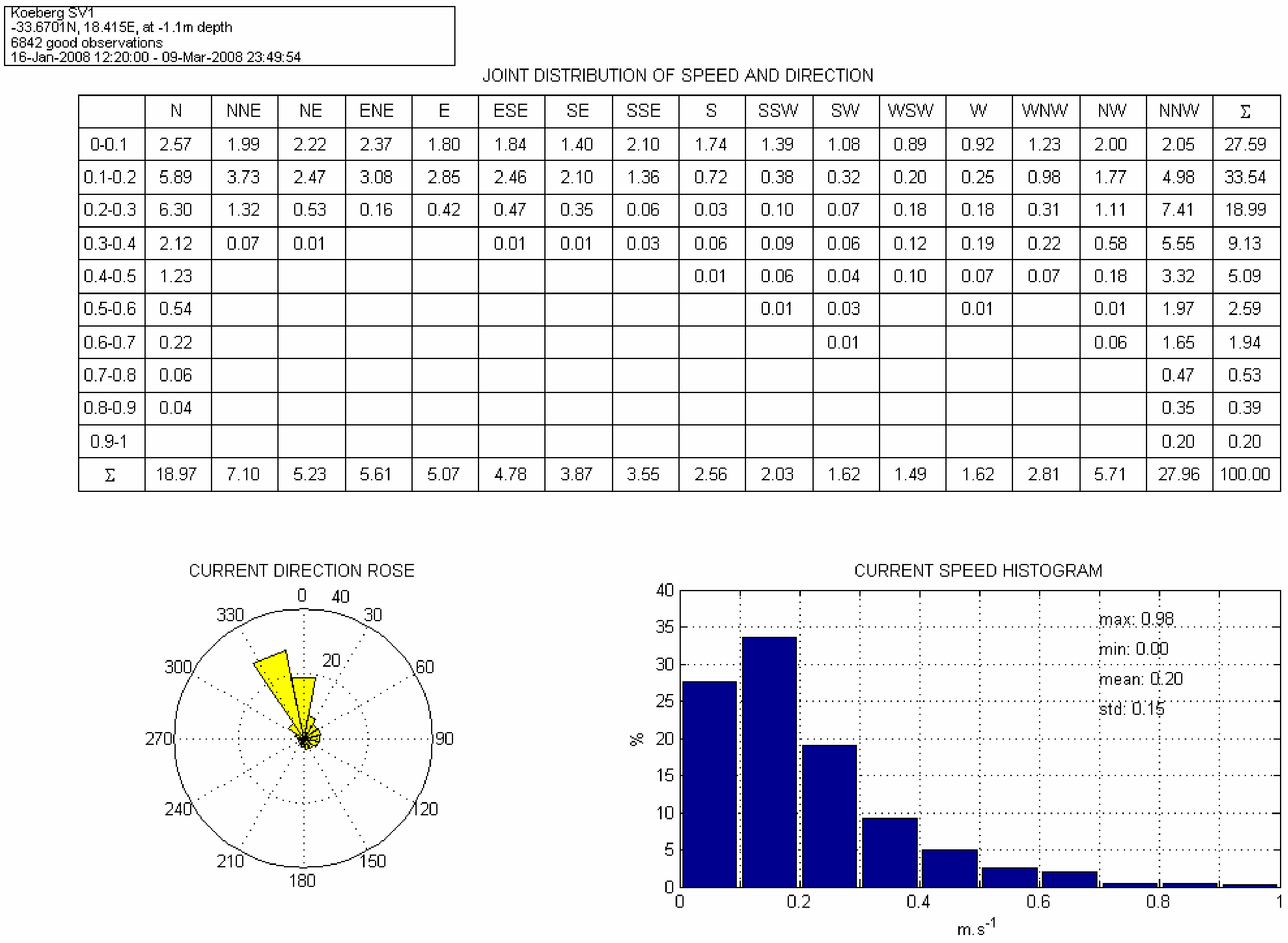


Figure 8: Summary plot of the ADCP's current data at 5.1m.



Koeberg SV1
-33.6701N, 18.415E, at -1.1m depth
6842 good observations
16-Jan-2008 12:20:00 - 09-Mar-2008 23:49:54

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	2.57	1.99	2.22	2.37	1.80	1.84	1.40	2.10	1.74	1.39	1.08	0.89	0.92	1.23	2.00	2.05	27.59
0.1-0.2	5.89	3.73	2.47	3.08	2.85	2.46	2.10	1.36	0.72	0.38	0.32	0.20	0.25	0.98	1.77	4.98	33.54
0.2-0.3	6.30	1.32	0.53	0.16	0.42	0.47	0.35	0.06	0.03	0.10	0.07	0.18	0.18	0.31	1.11	7.41	18.99
0.3-0.4	2.12	0.07	0.01			0.01	0.01	0.03	0.06	0.09	0.06	0.12	0.19	0.22	0.58	5.55	9.13
0.4-0.5	1.23								0.01	0.06	0.04	0.10	0.07	0.07	0.18	3.32	5.09
0.5-0.6	0.54									0.01	0.03		0.01		0.01	1.97	2.59
0.6-0.7	0.22										0.01				0.06	1.65	1.94
0.7-0.8	0.06															0.47	0.53
0.8-0.9	0.04															0.35	0.39
0.9-1																0.20	0.20
Σ	18.97	7.10	5.23	5.61	5.07	4.78	3.87	3.55	2.56	2.03	1.62	1.49	1.62	2.81	5.71	27.96	100.00

Figure 9: Summary plot of the ADCP's current data at 1.2m.

5.1.1.3 Progressive vector plot

Figure 10, Figure 11 and Figure 12 display progressive vector plots for depths of 8.9m, 5.1m and 1.2m, representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

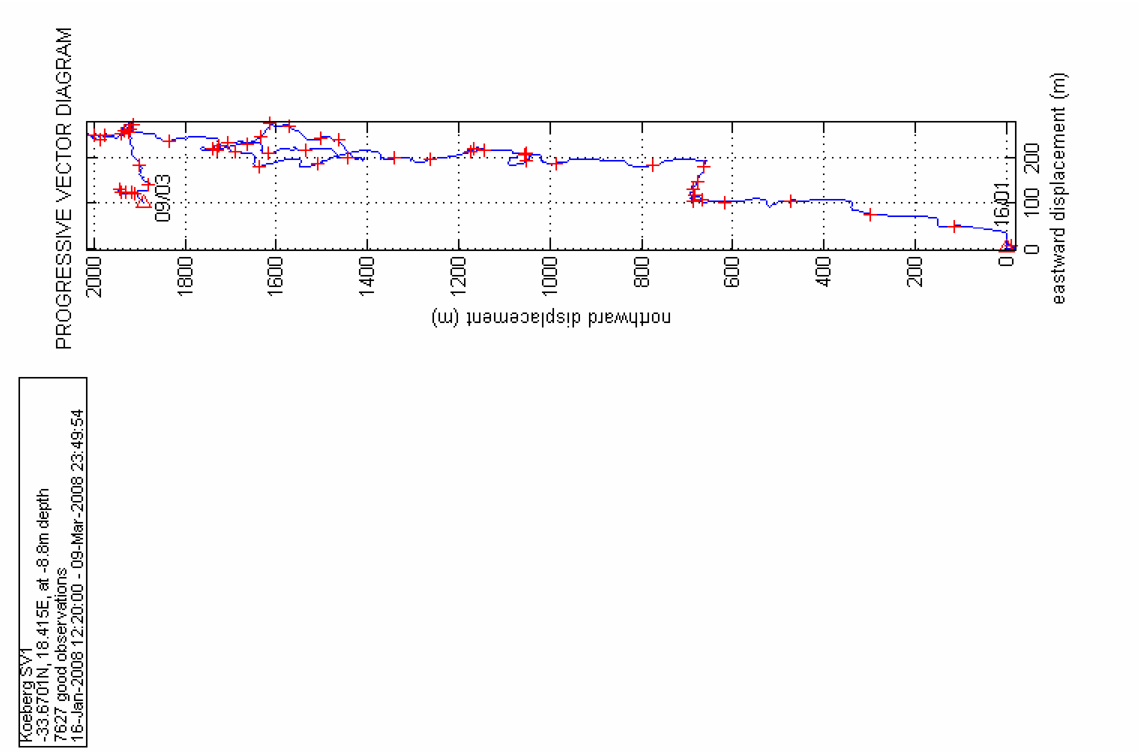


Figure 10: Progressive vector plot of current data at 8.9m.

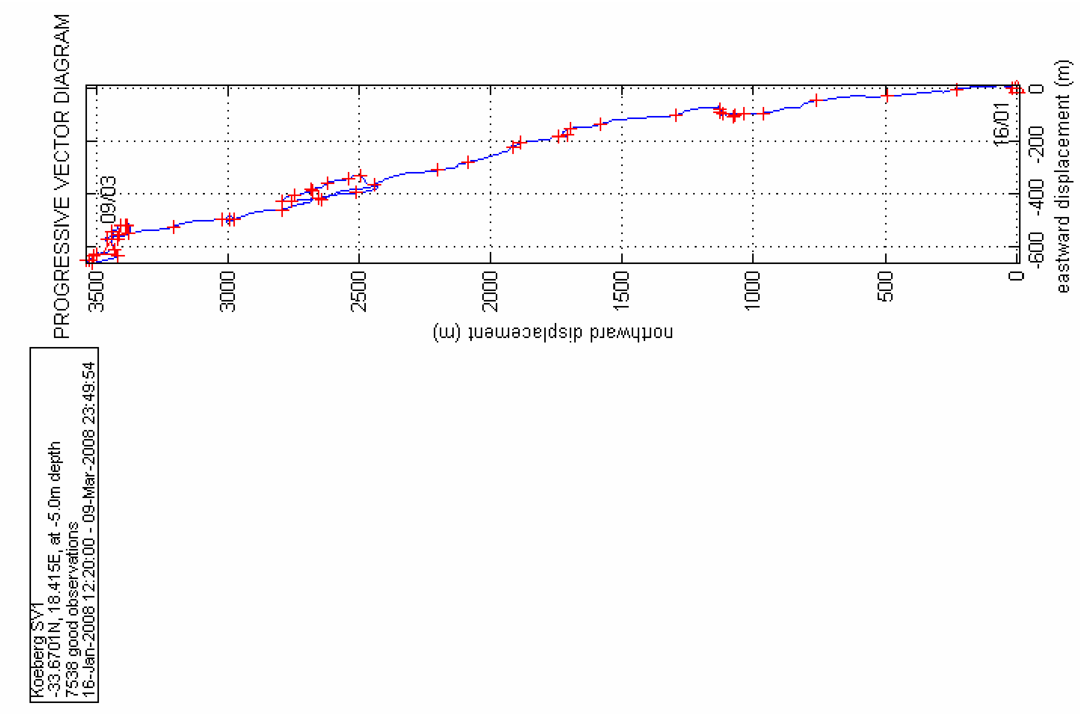


Figure 11: Progressive vector plot of current data at 5.1m.

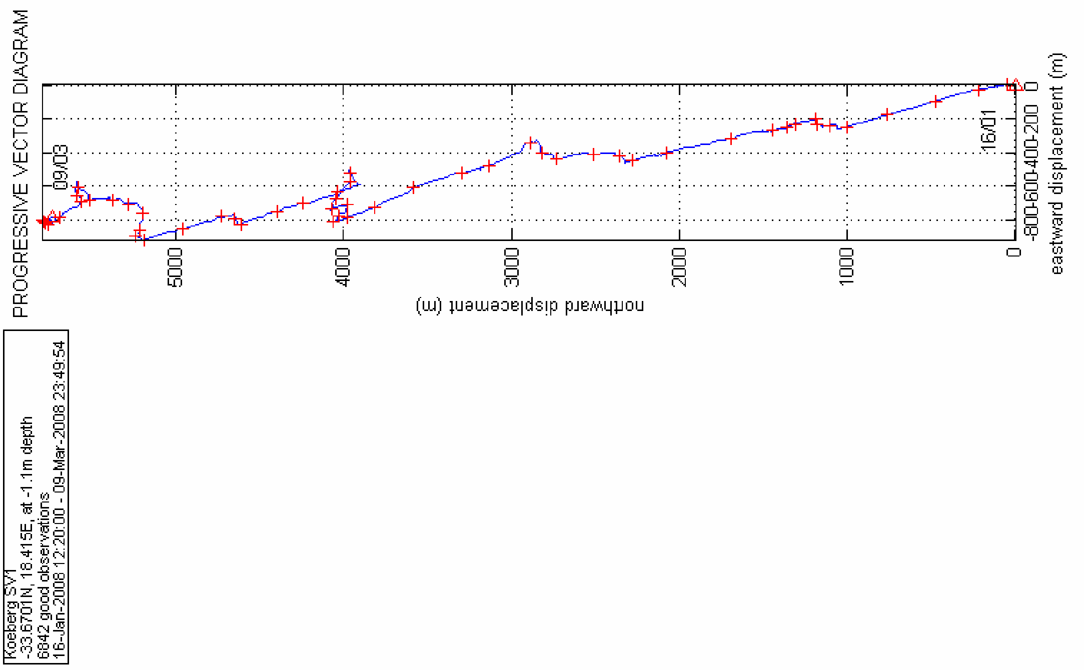


Figure 12: Progressive vector plot of current data at 1.2m.

5.1.1.4 Water property time series plot

The following figure displays a time series plot, which consists of:

- The first panel is of the water depth against time.
- The second panel is of the observed water temperature against time.

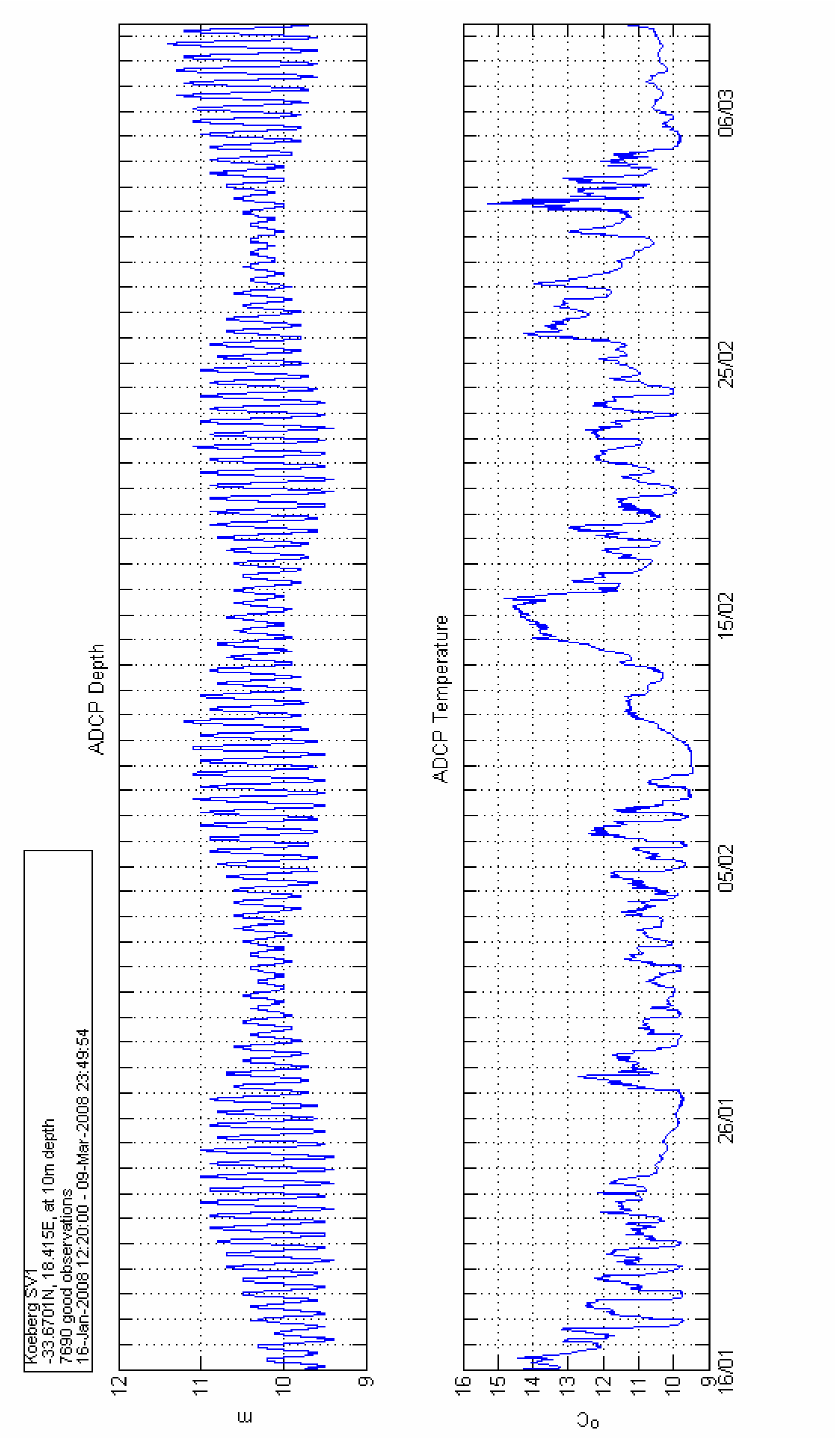


Figure 13: Time series of ADCP's water depth and water temperature.

5.1.2 Wave Data.

5.1.2.1 Time series plot

Figure 14 displays a time series plot of the main wave parameters:

- The first (upper) panel is of the significant wave height (Hs).
- The second panel is of the peak period (Tp).
- The third panel is of the peak wave direction (Dp).

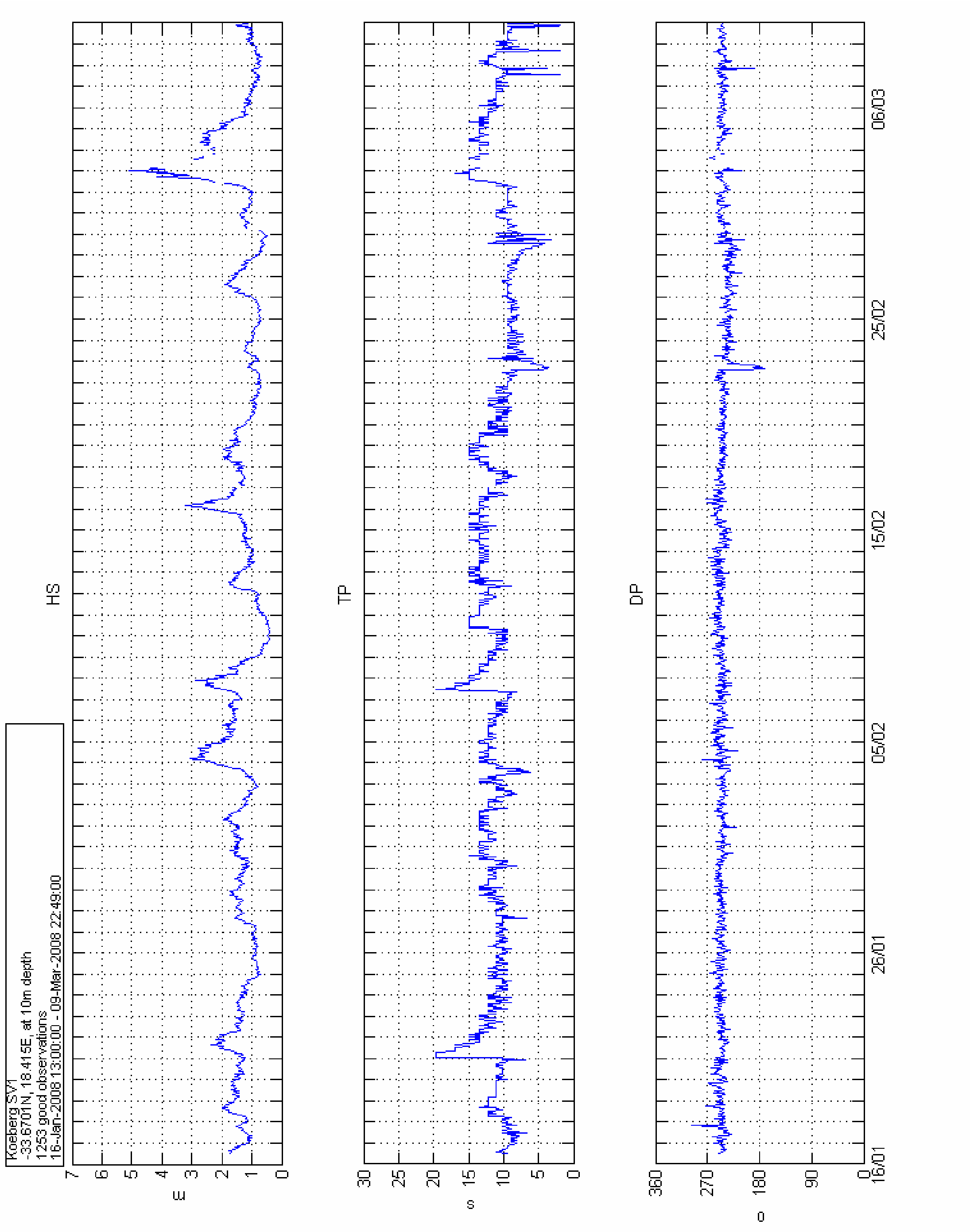


Figure 14: Times series of H_s, T_p and D_p.

5.1.2.2 Hs and Tp summary plot

Figure 15 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.1.2.3 Hs and Dp summary plot

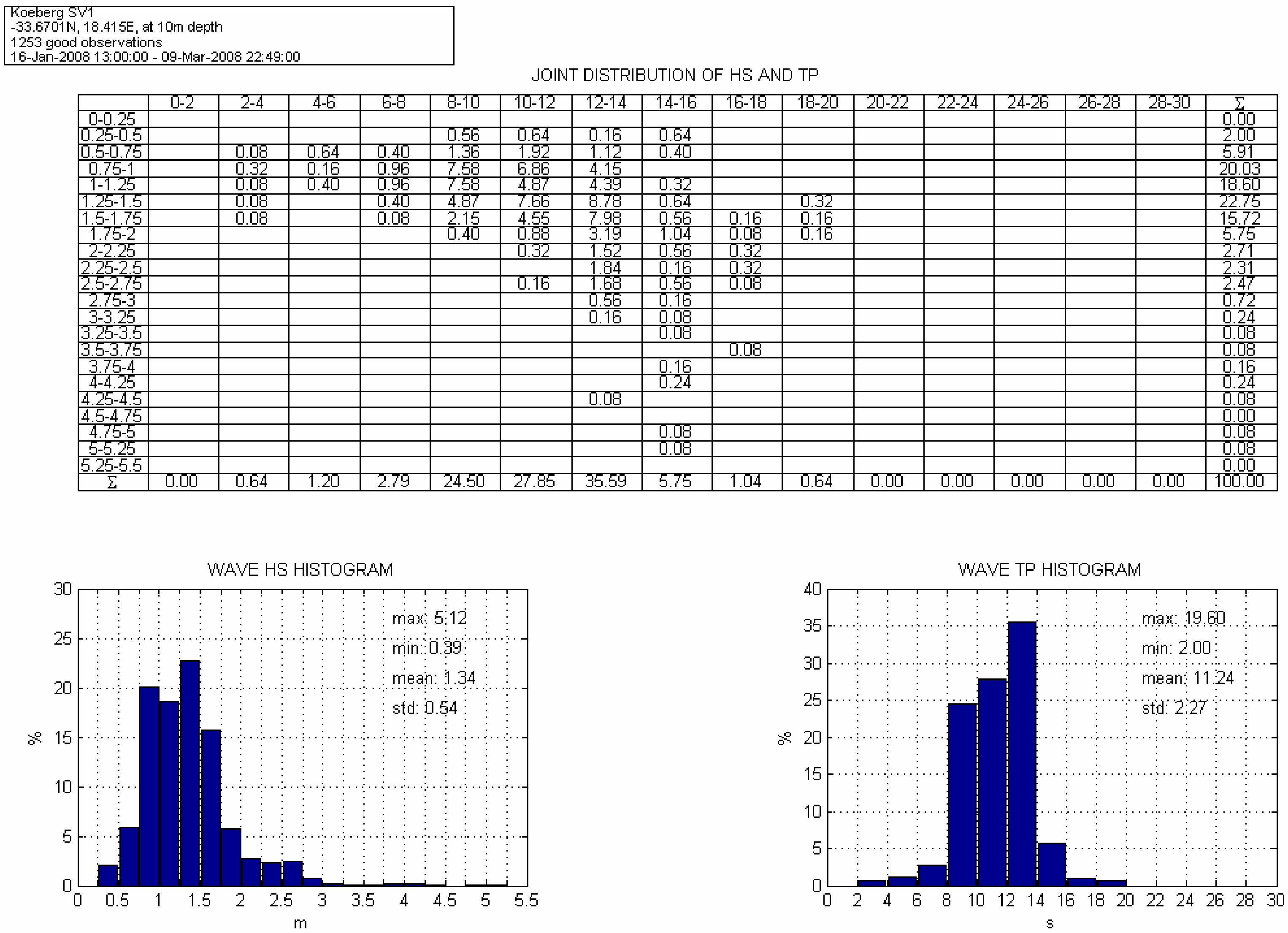
Figure 16 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.1.2.4 Tp and Dp summary plot

Figure 17 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

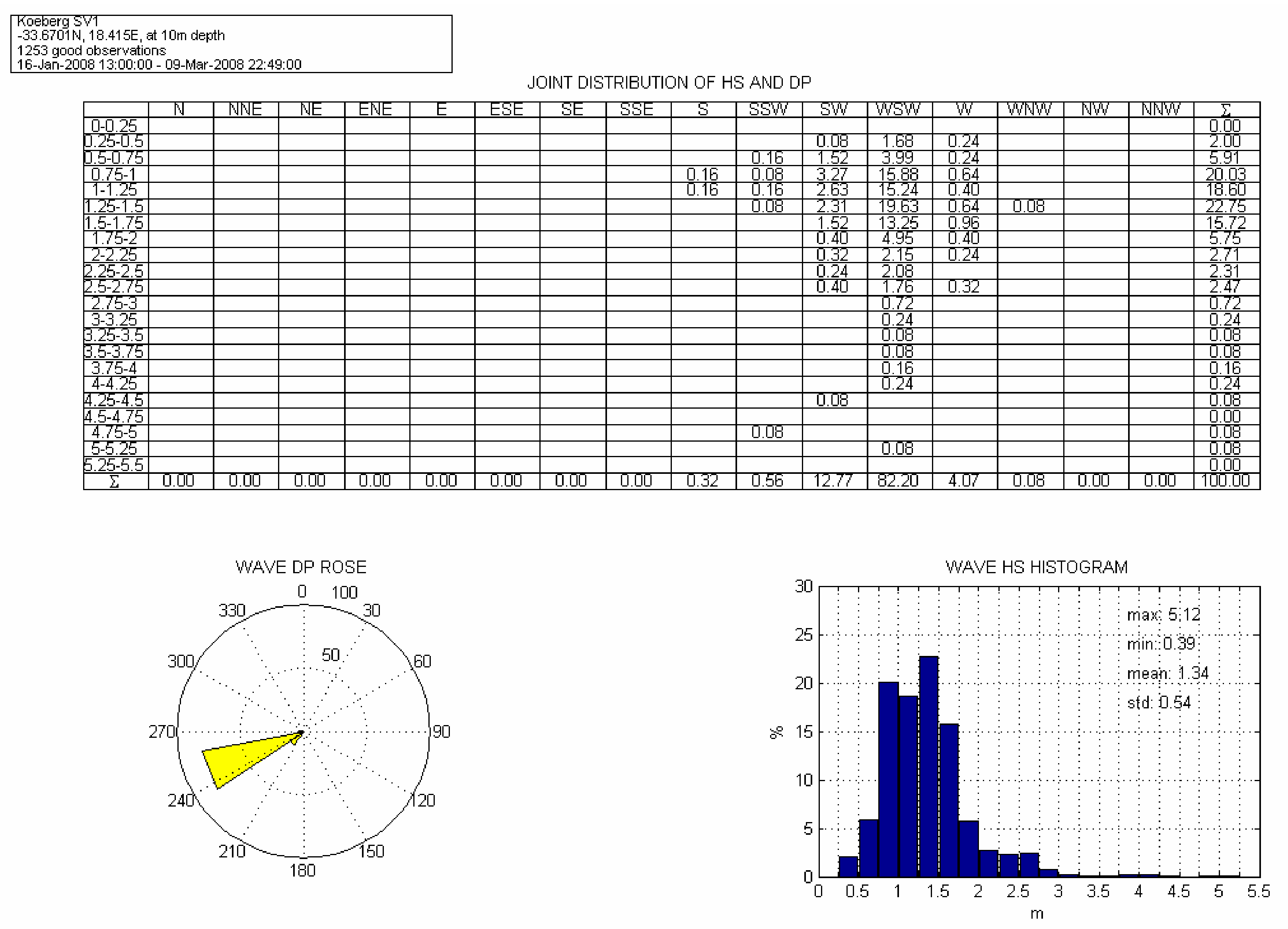


Koeberg SV1
-33.6701N, 18.415E, at 10m depth
1253 good observations
16-Jan-2008 13:00:00 - 09-Mar-2008 22:49:00

JOINT DISTRIBUTION OF HS AND TP

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5					0.56	0.64	0.16	0.64								2.00
0.5-0.75		0.08	0.64	0.40	1.36	1.92	1.12	0.40								5.91
0.75-1		0.32	0.16	0.96	7.58	6.86	4.15									20.03
1-1.25		0.08	0.40	0.96	7.58	4.87	4.39	0.32								18.60
1.25-1.5		0.08		0.40	4.87	7.66	8.78	0.64		0.32						22.75
1.5-1.75		0.08		0.08	2.15	4.55	7.98	0.56	0.16	0.16						15.72
1.75-2					0.40	0.88	3.19	1.04	0.08	0.16						5.75
2-2.25						0.32	1.52	0.56	0.32							2.71
2.25-2.5							1.84	0.16	0.32							2.31
2.5-2.75						0.16	1.68	0.56	0.08							2.47
2.75-3							0.56	0.16								0.72
3-3.25							0.16	0.08								0.24
3.25-3.5								0.08								0.08
3.5-3.75									0.08							0.08
3.75-4								0.16								0.16
4-4.25								0.24								0.24
4.25-4.5							0.08									0.08
4.5-4.75																0.00
4.75-5								0.08								0.08
5-5.25								0.08								0.08
5.25-5.5																0.00
Σ	0.00	0.64	1.20	2.79	24.50	27.85	35.59	5.75	1.04	0.64	0.00	0.00	0.00	0.00	0.00	100.00

Figure 15: Summary plot of H_s and T_p.

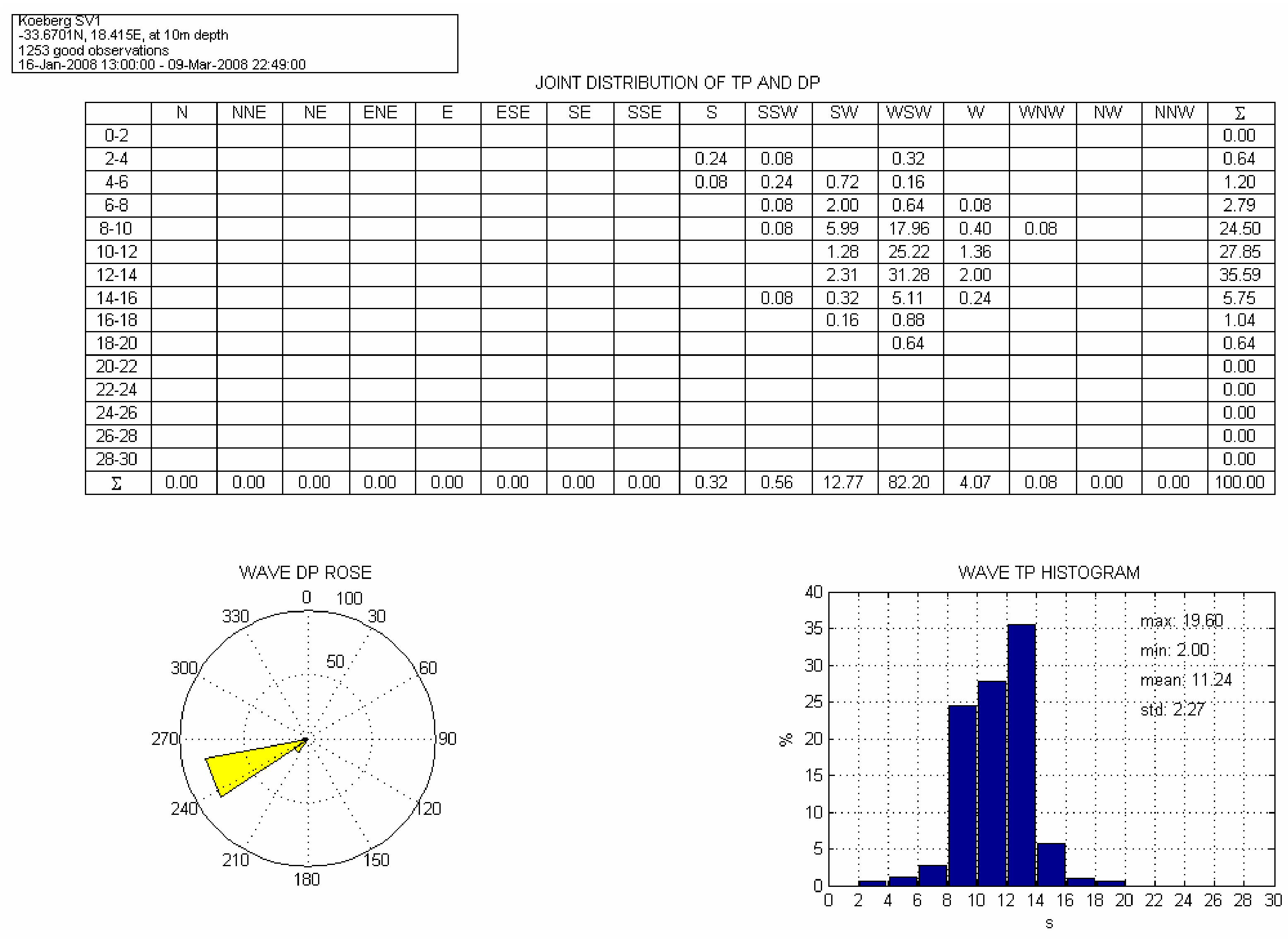


Koeberg SV1
-33.6701N, 18.415E, at 10m depth
1253 good observations
16-Jan-2008 13:00:00 - 09-Mar-2008 22:49:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5											0.08	1.68	0.24				2.00
0.5-0.75										0.16	1.52	3.99	0.24				5.91
0.75-1									0.16	0.08	3.27	15.88	0.64				20.03
1-1.25									0.16	0.16	2.63	15.24	0.40				18.60
1.25-1.5										0.08	2.31	19.63	0.64	0.08			22.75
1.5-1.75											1.52	13.25	0.96				15.72
1.75-2											0.40	4.95	0.40				5.75
2-2.25											0.32	2.15	0.24				2.71
2.25-2.5											0.24	2.08					2.31
2.5-2.75											0.40	1.76	0.32				2.47
2.75-3												0.72					0.72
3-3.25												0.24					0.24
3.25-3.5												0.08					0.08
3.5-3.75												0.08					0.08
3.75-4												0.16					0.16
4-4.25												0.24					0.24
4.25-4.5											0.08						0.08
4.5-4.75																	0.00
4.75-5										0.08							0.08
5-5.25												0.08					0.08
5.25-5.5																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.56	12.77	82.20	4.07	0.08	0.00	0.00	100.00

Figure 16: Summary plot of H_s and D_p.



Koeberg SV1
-33.6701N, 18.415E, at 10m depth
1253 good observations
16-Jan-2008 13:00:00 - 09-Mar-2008 22:49:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4									0.24	0.08		0.32					0.64
4-6									0.08	0.24	0.72	0.16					1.20
6-8										0.08	2.00	0.64	0.08				2.79
8-10										0.08	5.99	17.96	0.40	0.08			24.50
10-12											1.28	25.22	1.36				27.85
12-14											2.31	31.28	2.00				35.59
14-16										0.08	0.32	5.11	0.24				5.75
16-18											0.16	0.88					1.04
18-20												0.64					0.64
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.56	12.77	82.20	4.07	0.08	0.00	0.00	100.00

Figure 17: Summary plot of T_p and D_p.

5.1.2.5 Wave spectral plot

The figure on the following pages display wave spectral plots for significant waves events. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

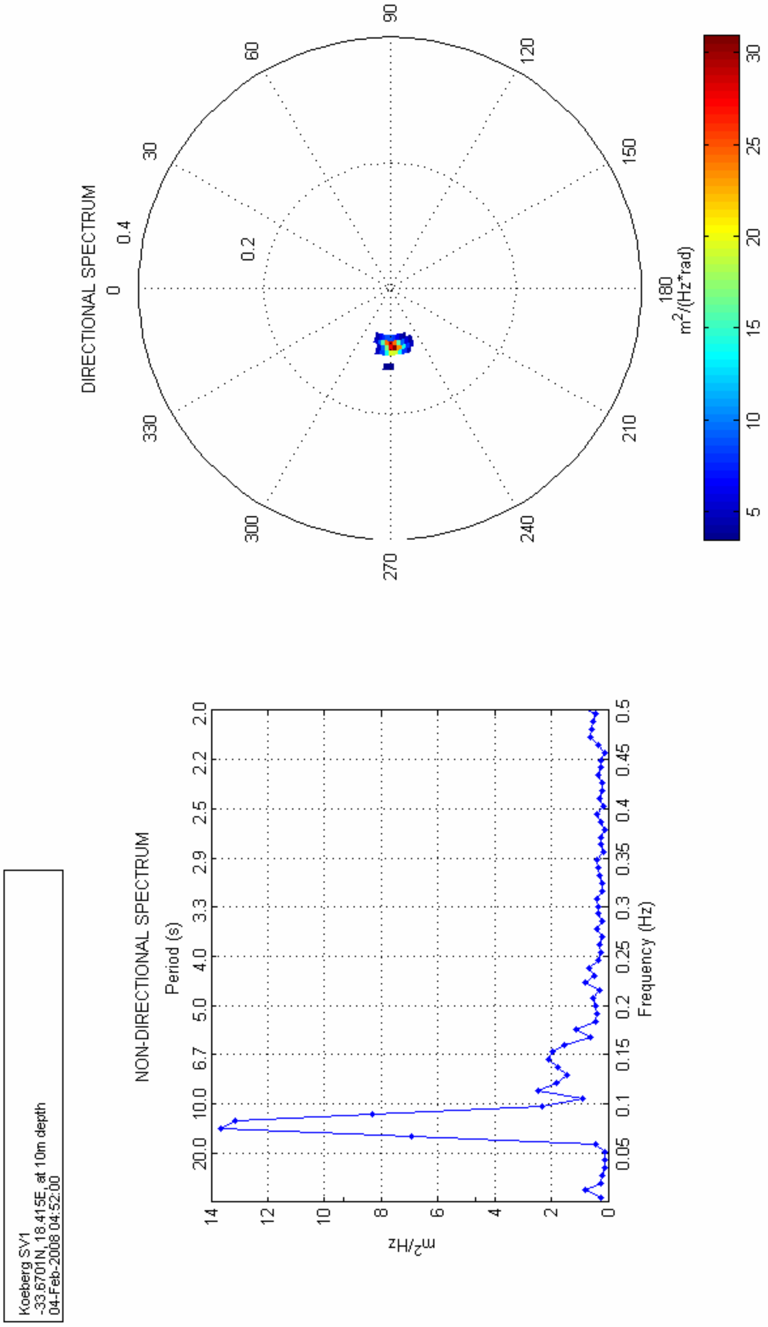


Figure 18: Wave spectra for 4th of February 2008 at 04:52:00.

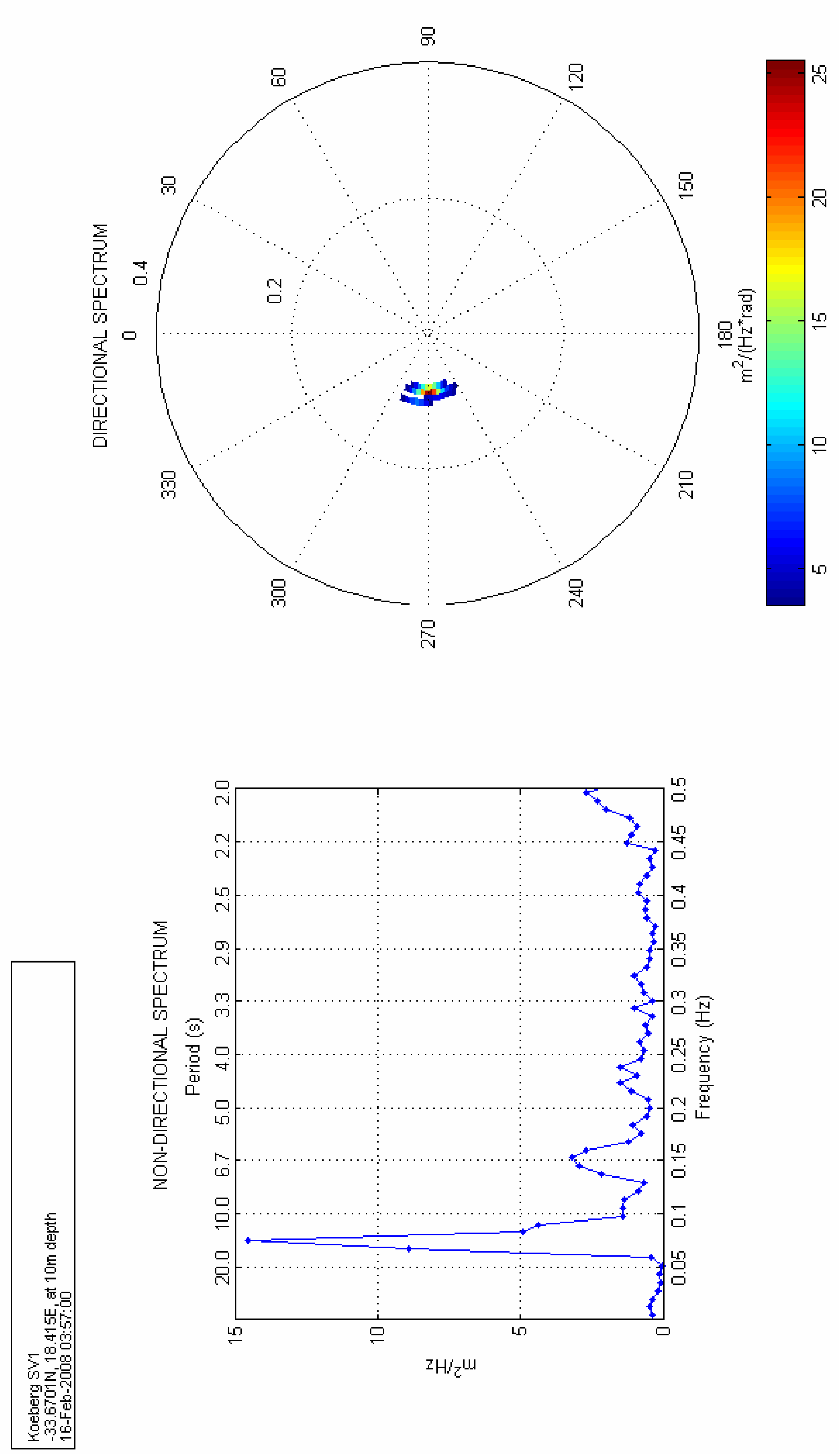


Figure 19: Wave spectra for 16th of February 2008 at 03:57:00.

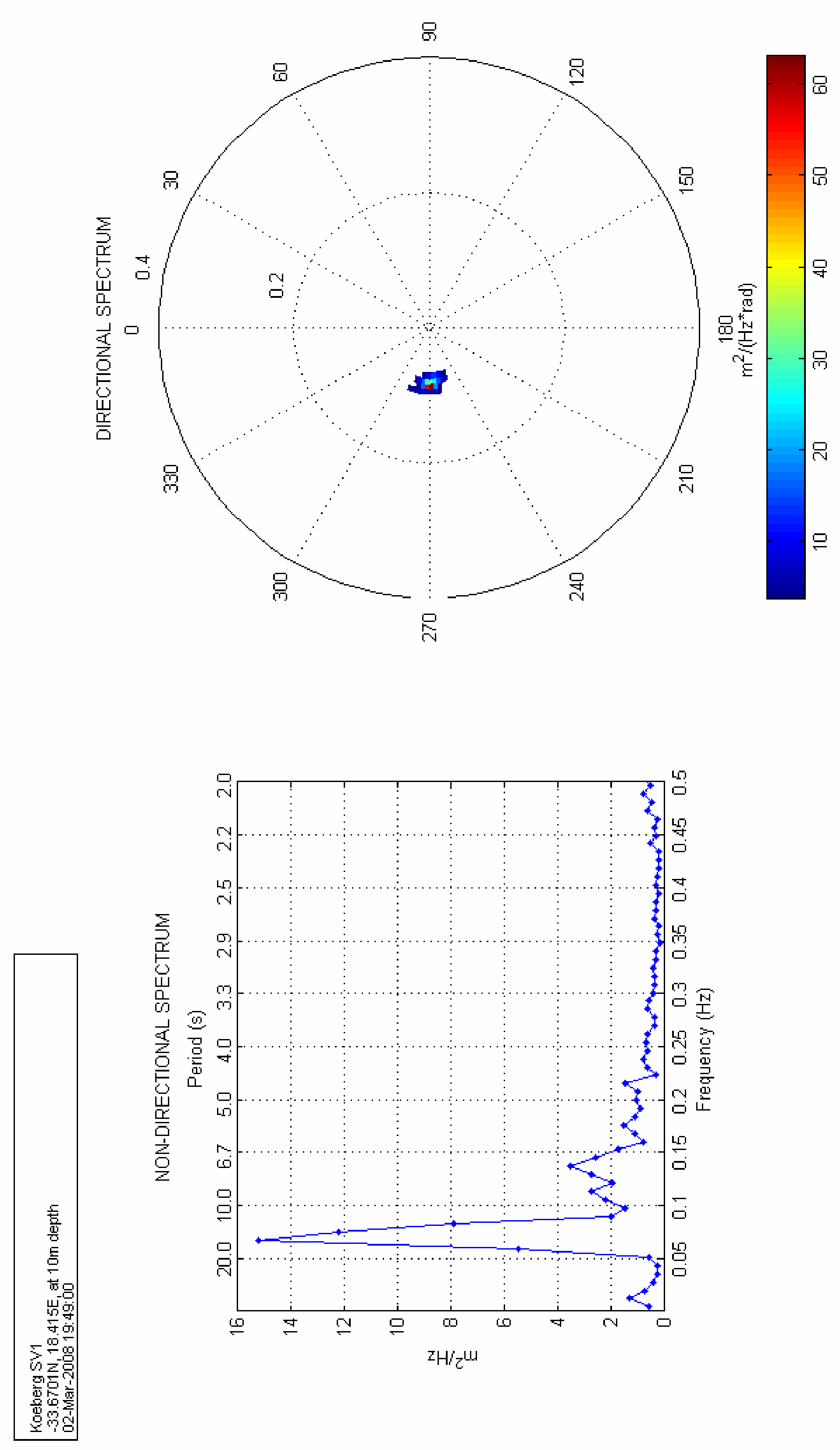


Figure 20: Wave spectra for 2nd of March 2008 at 19:49:00.

5.2 RBR-CT LOGGER

5.2.1 Temperature and Salinity Data

5.2.1.1 Time series plot

Figure 21 displays a time series plot, which consists of:

- The first panel is of the observed water temperature against time.
- The second panel is of the derived salinity against time.

5.2.1.2 Summary plot

Figure 22 displays a summary plot, which consists of:

- The top panel is a histogram of the water temperature. This reflects the percentage of observations that fall within each temperature interval. Included on the plot are basic statistics for the distribution.
- The bottom panel is a histogram of the water salinity.

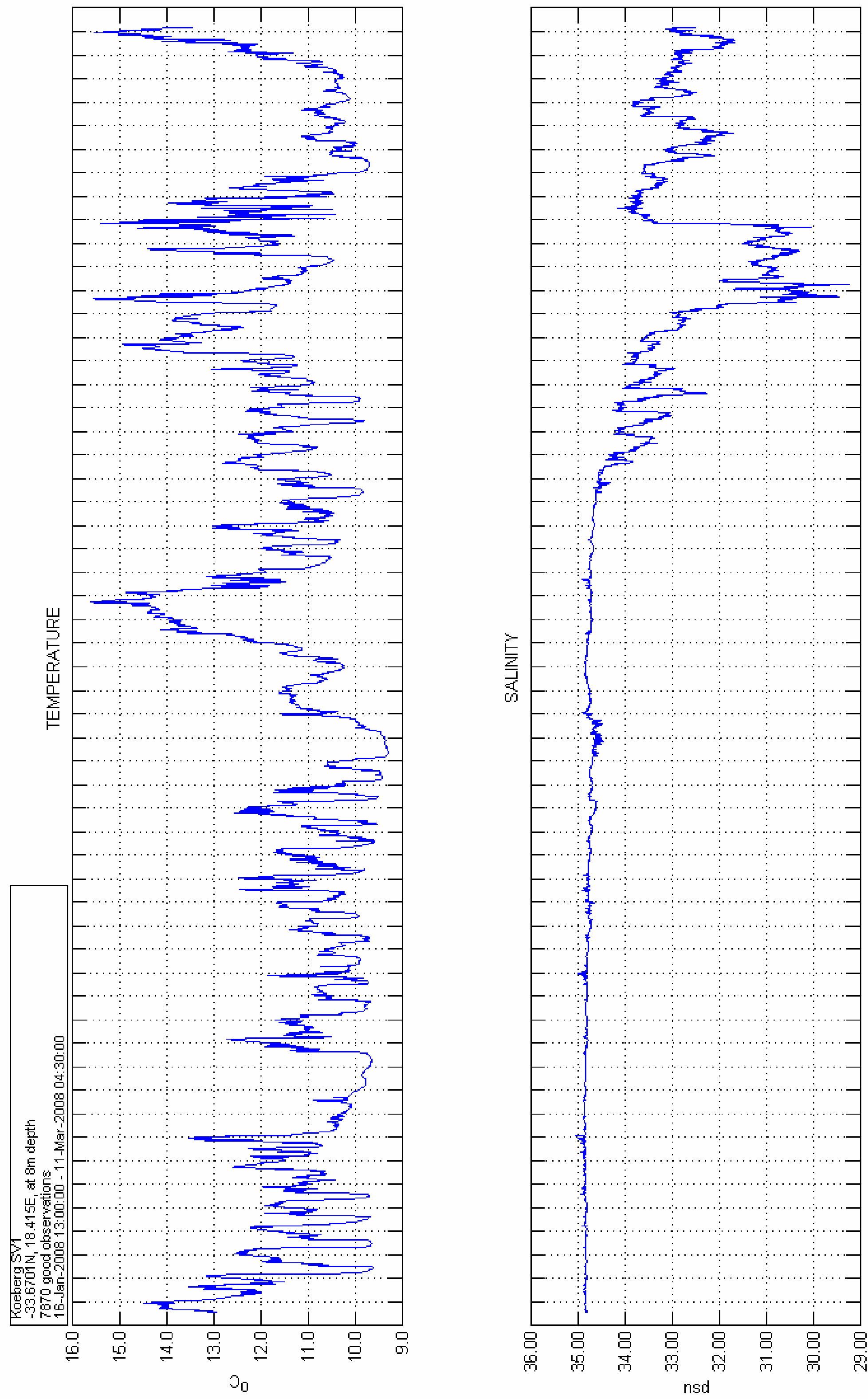


Figure 21: Time series of temperature and salinity from the RBR logger.

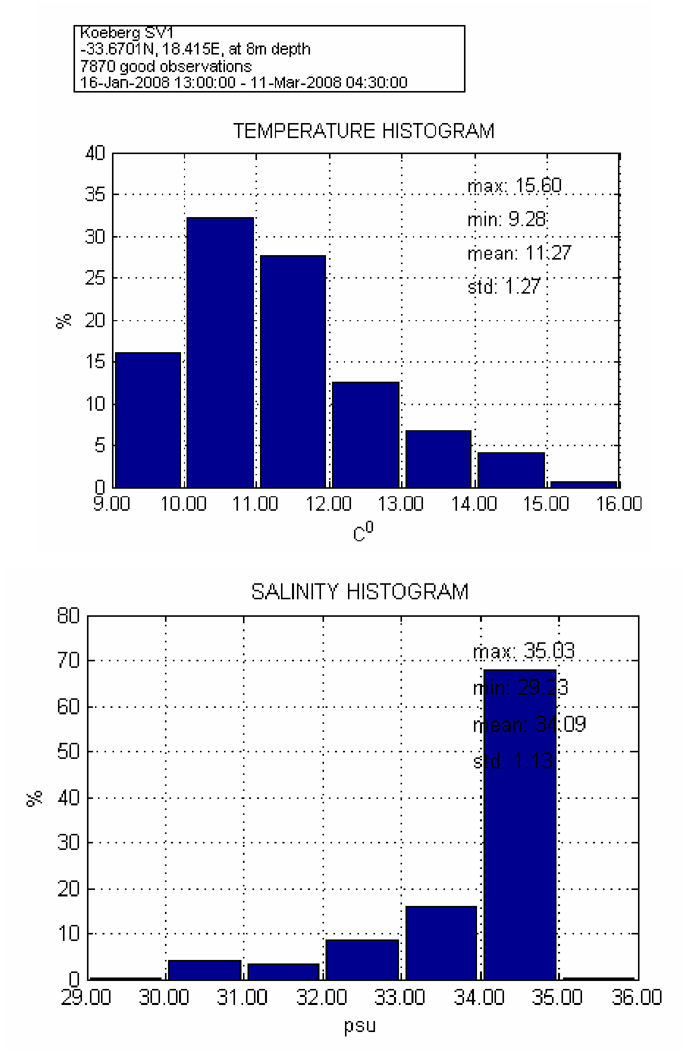


Figure 22: Summary histograms of temperature and salinity.

5.3 SEDIMENTS, BIOFOULING AND WATER SAMPLES.

Analysis of sediment and water samples were undertaken by the CSIR and results are presented as an appendage (Section 8, page 52).

6. DISCUSSION

The first set of oceanographic data collected ~1 km off the coast of Koeberg (33°40.206' S, 18°24.897' E) for the period between January 16th and March 11th 2008 has been presented in this report. The measurements taken fall within a larger dataset being compiled to assist a preliminary safety survey of multiple sites around the South African coast reports for Eskom.

At the Koeberg site, 1 600 kHz ADCP and 2 RBR-CT loggers have been deployed to measure currents, waves and water temperature and salinity. The ADCP is fixed on a frame at ~10m and the RBR loggers are moored at ~3m and ~8m below the surface. During recovery of the data, undertaken during March 10th – 13th 2008, it was found that only 1 RBR-CT loggers functioned properly. The instrument at 3m failed to capture data and was sent for repairs. Consequently, data from only 1 RBR logger was presented in this report. In addition, the ADCP's pitch and roll showed a deviation of over 30° after March 3rd, which is beyond recommended levels. This may have been due to the ADCP's onboard battery approaching the end of its life. Therefore, ADCP data after March 3rd must be interpreted conservatively. Nonetheless, the overall percentage data return for both the ADCP and the RBR logger after careful quality control was found to be good.

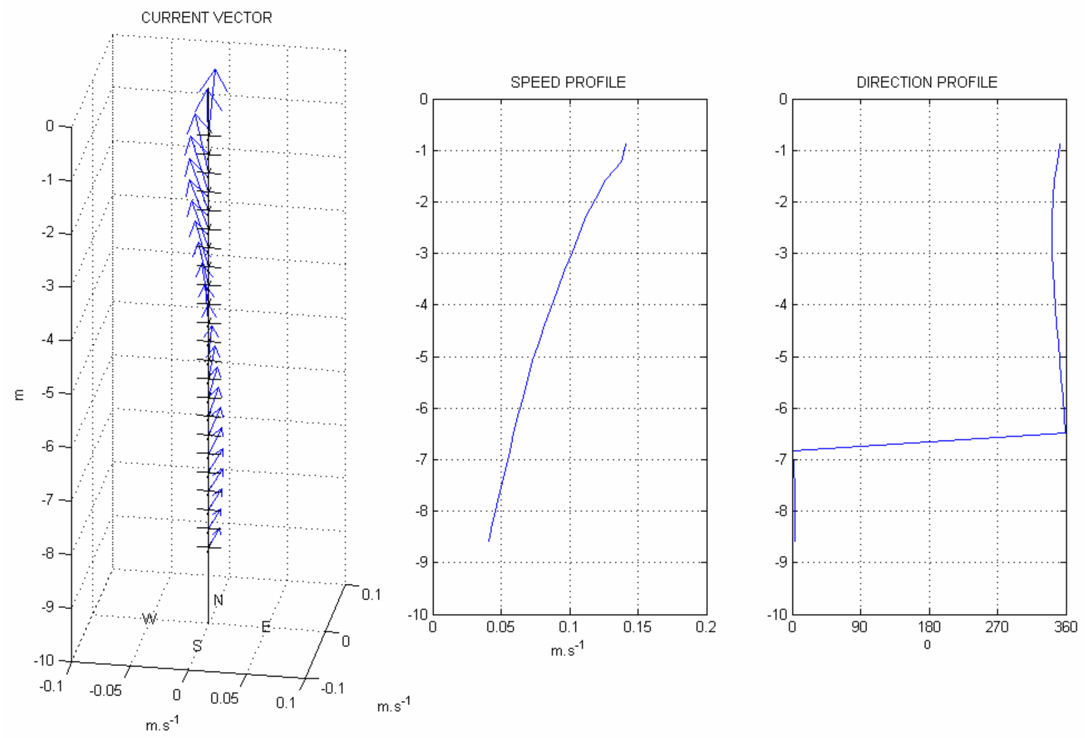


Figure 23: Mean profile plot.

Sediments, water and beach samples were also collected during the service visit and analysis was undertaken at the CSIR.

The average surface current speed at site was ~0.2ms^{-1}, decreasing to ~0.1ms^{-1} at 8m depth. The surface flow was mostly towards the North-North-West, while at depth, it was mainly towards the North. The variability in both the direction and speed of the current was large at depth. The mean current profile plot, presented in Figure

23, shows the gradual decrease in the vector mean speed. In addition, it also shows that the direction of the current was predominantly towards the N – NNW over the water column.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.34m, with a wave period of 11.24s and mean direction to WSW.

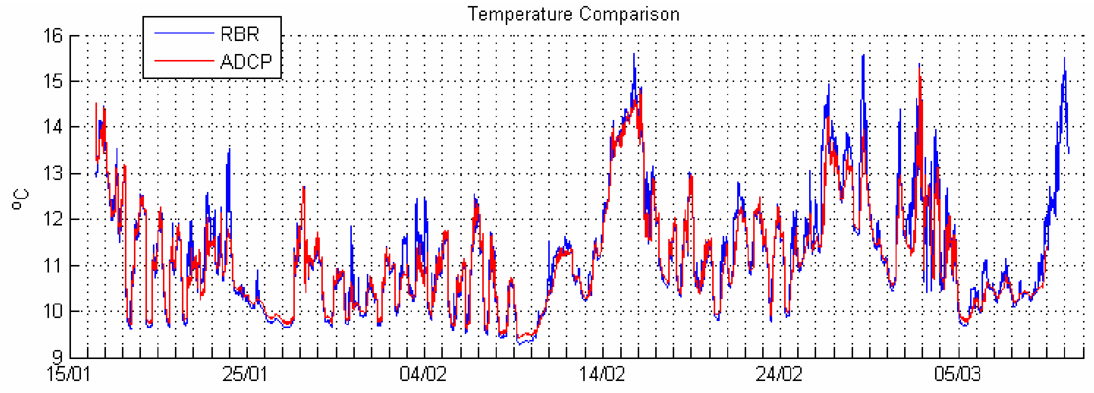


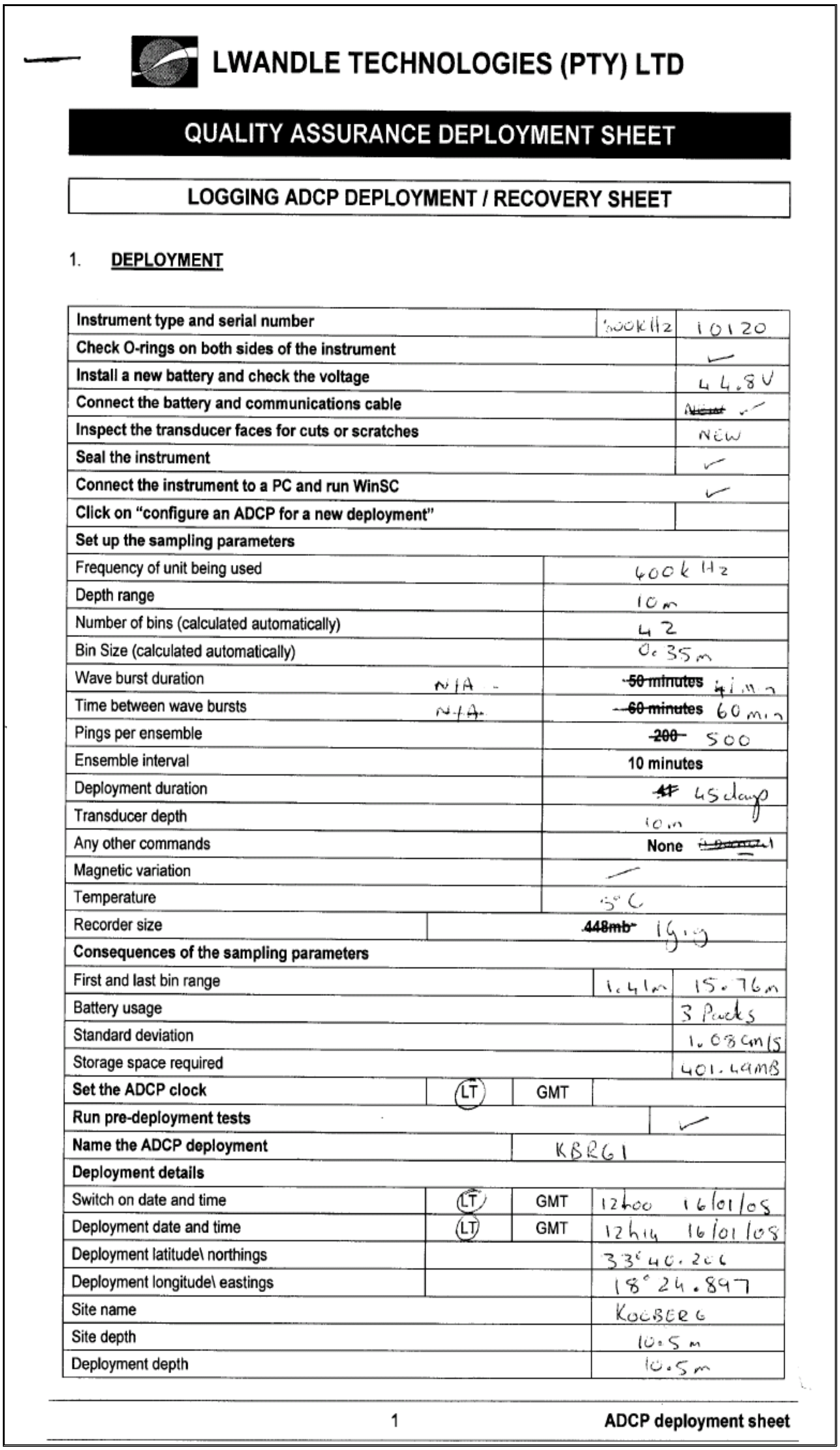
Figure 24: Comparison of temperature recorded by the RBR CT logger and the temperature sensor on the ADCP.

In Figure 21 shows that salinity values started to drift after February 20th 2008, reaching a minimum of ~29.0 psu on February 29th. This indicates some degree of biofouling.

Although the mooring was not fitted with a tide gauge to measure variations in water level, the ADCP appeared to collect meaningful pressure and depth data. The data from the sensor showed a semi-diurnal tidal signal with range of ~0.75m. A gradual increase in water level can be observed in Figure 13. During recovery of the ADCP, the divers noticed that the frame was completely sanded over. This would account for the erroneous increase in water level observed in the data.

7. INSTRUMENT PARTICULARS FOR SERVICE VISIT ONE

7.1 ADCP MOBILISATION AND SERVICE VISIT DEPLOYMENT SHEETS



LWANDLE TECHNOLOGIES (PTY) LTD

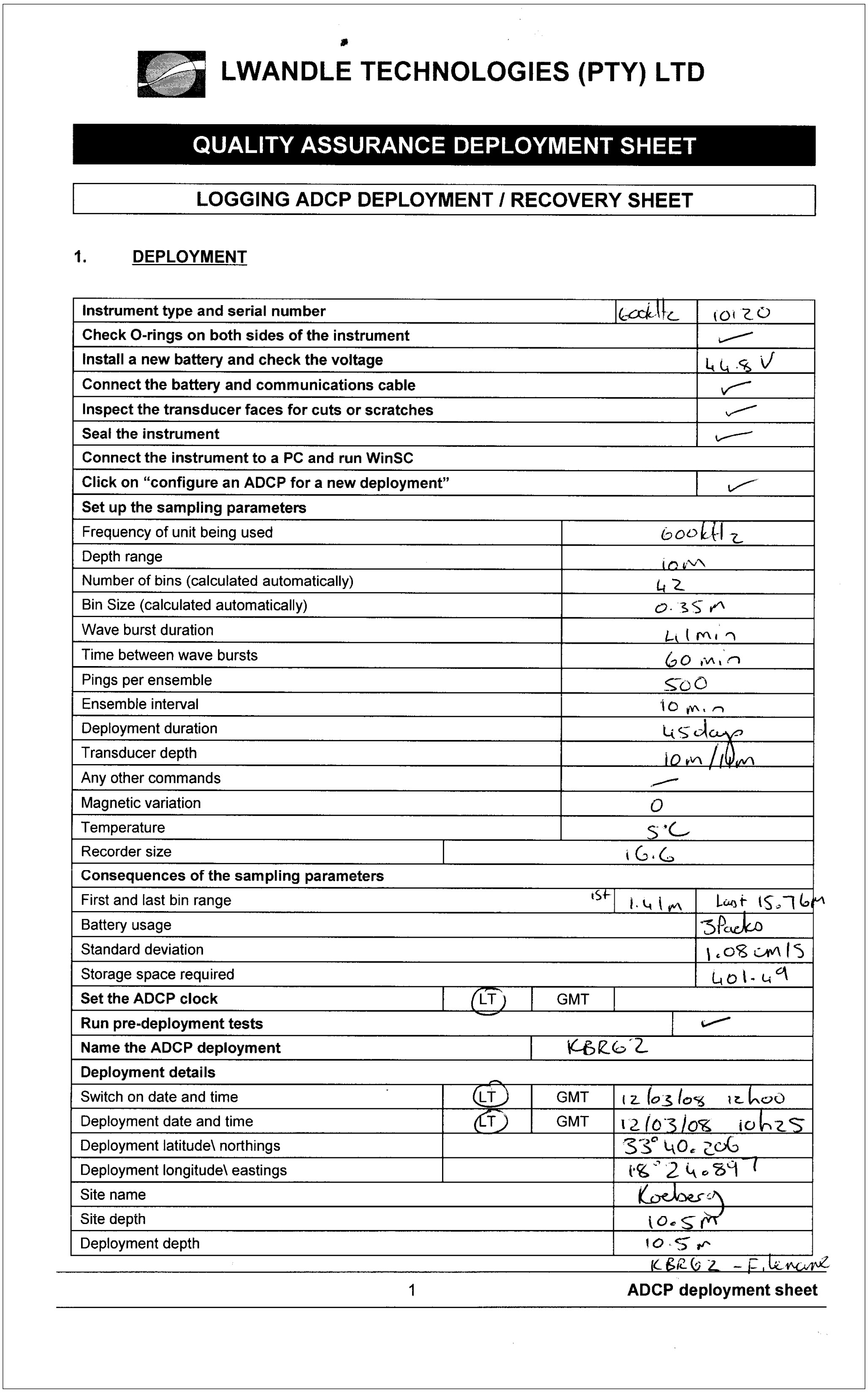
QUALITY ASSURANCE DEPLOYMENT SHEET

LOGGING ADCP DEPLOYMENT / RECOVERY SHEET

1. **DEPLOYMENT**

Instrument type and serial number		600kHz	10120
Check O-rings on both sides of the instrument			✓
Install a new battery and check the voltage			44.8V
Connect the battery and communications cable			~~New~~ ✓
Inspect the transducer faces for cuts or scratches			NEW
Seal the instrument			✓
Connect the instrument to a PC and run WinSC			✓
Click on "configure an ADCP for a new deployment"			
Set up the sampling parameters			
Frequency of unit being used			400kHz
Depth range			10m
Number of bins (calculated automatically)			42
Bin Size (calculated automatically)			0.35m
Wave burst duration	N/A -		~~50 minutes~~ 41min
Time between wave bursts	N/A		~~60 minutes~~ 60min
Pings per ensemble			~~200~~ 500
Ensemble interval			10 minutes
Deployment duration			~~41~~ 45days
Transducer depth			10m
Any other commands			None ~~[illegible]~~
Magnetic variation			—
Temperature			5°C
Recorder size			~~448mb~~ 1Gig
Consequences of the sampling parameters			
First and last bin range		1.41m	15.76m
Battery usage			3 Packs
Standard deviation			1.08cm/s
Storage space required			401.49MB
Set the ADCP clock	[✓ LT]	GMT	
Run pre-deployment tests			✓
Name the ADCP deployment			KBRG1
Deployment details			
Switch on date and time	[✓ LT]	GMT	12h00 16/01/05
Deployment date and time	[✓ LT]	GMT	12h14 16/01/08
Deployment latitude\ northings			33°40.206
Deployment longitude\ eastings			18°24.897
Site name			KOEBERG
Site depth			10.5m
Deployment depth			10.5m

1 **ADCP deployment sheet**



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

LOGGING ADCP DEPLOYMENT / RECOVERY SHEET

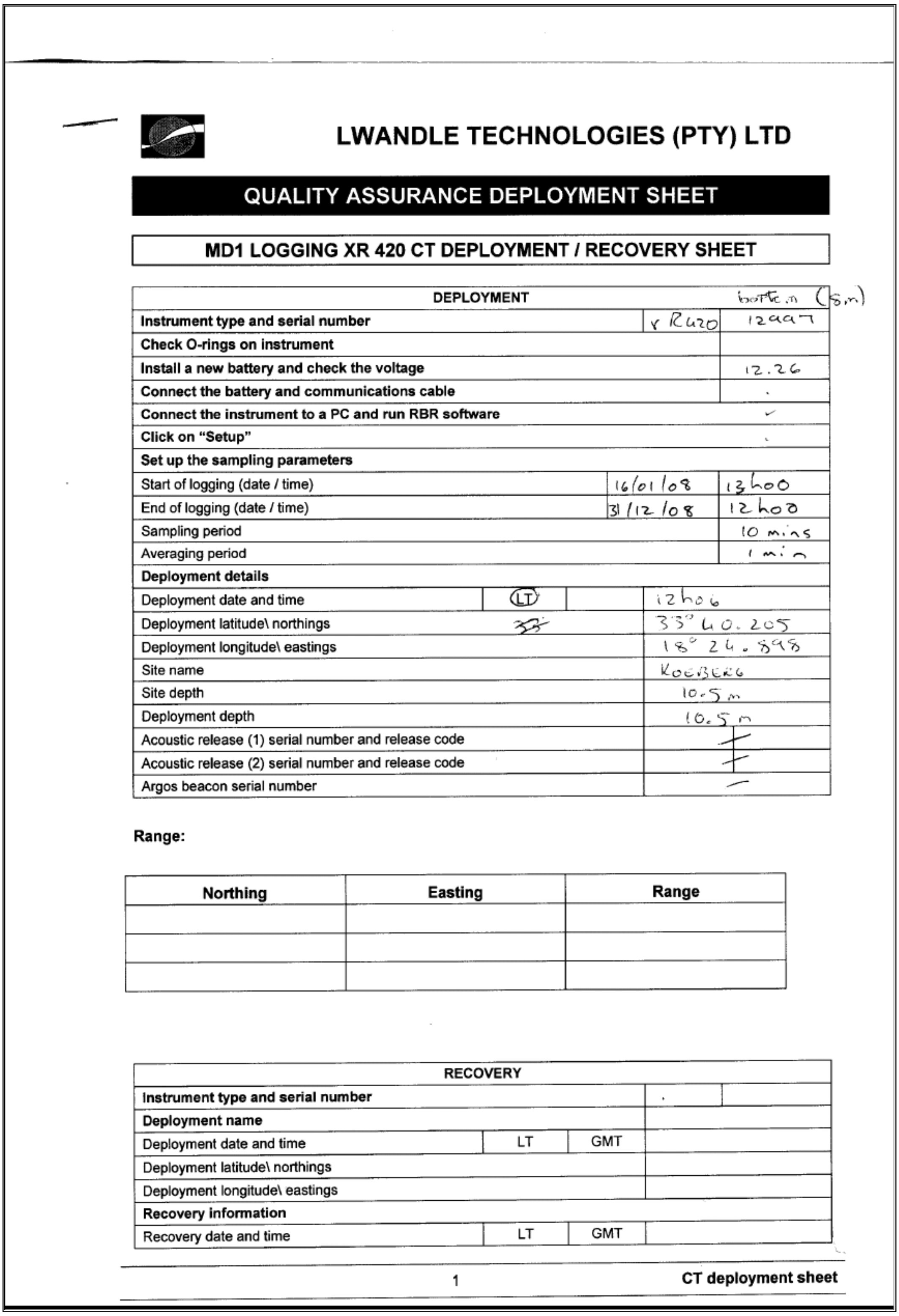
1. DEPLOYMENT

Instrument type and serial number		600kHz	10120
Check O-rings on both sides of the instrument			✓
Install a new battery and check the voltage			44.8V
Connect the battery and communications cable			✓
Inspect the transducer faces for cuts or scratches			✓
Seal the instrument			✓
Connect the instrument to a PC and run WinSC			
Click on "configure an ADCP for a new deployment"			✓
Set up the sampling parameters			
Frequency of unit being used	600kHz		
Depth range	10m		
Number of bins (calculated automatically)	42		
Bin Size (calculated automatically)	0.35m		
Wave burst duration	41min		
Time between wave bursts	60 min		
Pings per ensemble	500		
Ensemble interval	10 min		
Deployment duration	45days		
Transducer depth	10m/10m		
Any other commands	—		
Magnetic variation	0		
Temperature	5°C		
Recorder size	16.6		
Consequences of the sampling parameters			
First and last bin range	1st	1.41m	Last 15.76m
Battery usage			3Packs
Standard deviation			1.08cm/S
Storage space required			401.49
Set the ADCP clock	[✓ LT]	GMT	
Run pre-deployment tests			✓
Name the ADCP deployment		KBR62	
Deployment details			
Switch on date and time	[✓ LT]	GMT	12/03/08 12h00
Deployment date and time	[✓ LT]	GMT	12/03/08 10h25
Deployment latitude\ northings			33°40.206
Deployment longitude\ eastings			18°24.897
Site name			Koeberg
Site depth			10.5m
Deployment depth			10.5m

KBR62 - Filename

1 ADCP deployment sheet

7.2 RBR-CT LOGGER MOBILISATION AND SERVICE VISIT DEPLOYMENT SHEETS



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

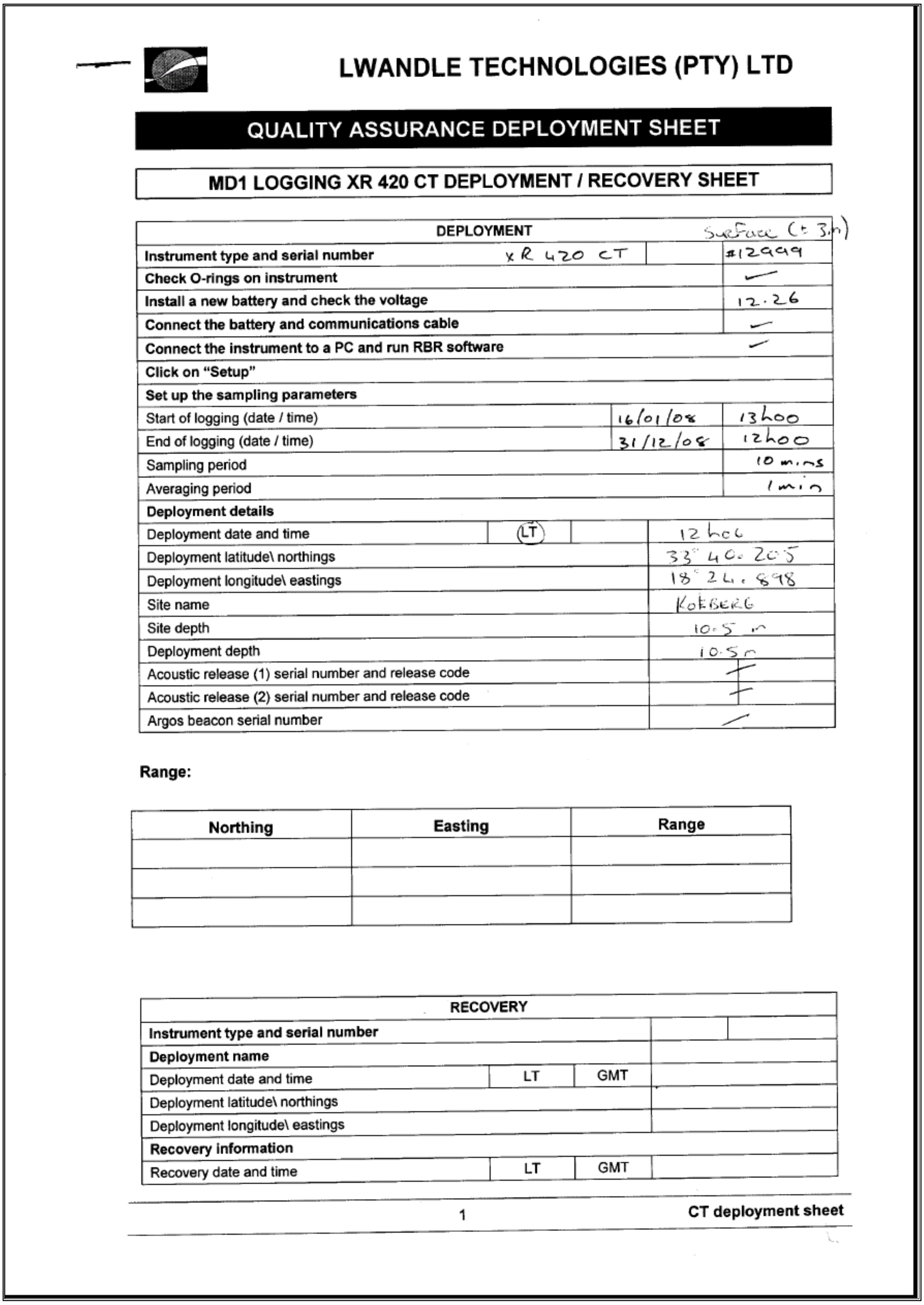
DEPLOYMENT			bottom (8m)
Instrument type and serial number		XR420	12997
Check O-rings on instrument			
Install a new battery and check the voltage			12.26
Connect the battery and communications cable			
Connect the instrument to a PC and run RBR software			✓
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		16/01/08	13h00
End of logging (date / time)		31/12/08	12h00
Sampling period			10 mins
Averaging period			1 min
Deployment details			
Deployment date and time	[✓ LT]		12h06
Deployment latitude\ northings	~~33~~		33° 40.205
Deployment longitude\ eastings			18° 24.898
Site name			KOEBERG
Site depth			10.5m
Deployment depth			10.5m
Acoustic release (1) serial number and release code			―
Acoustic release (2) serial number and release code			―
Argos beacon serial number			―

Range:

Northing	Easting	Range

RECOVERY			
Instrument type and serial number			
Deployment name			
Deployment date and time	LT	GMT	
Deployment latitude\ northings			
Deployment longitude\ eastings			
Recovery information			
Recovery date and time	LT	GMT	

1 **CT deployment sheet**



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

Surface (± 3m)

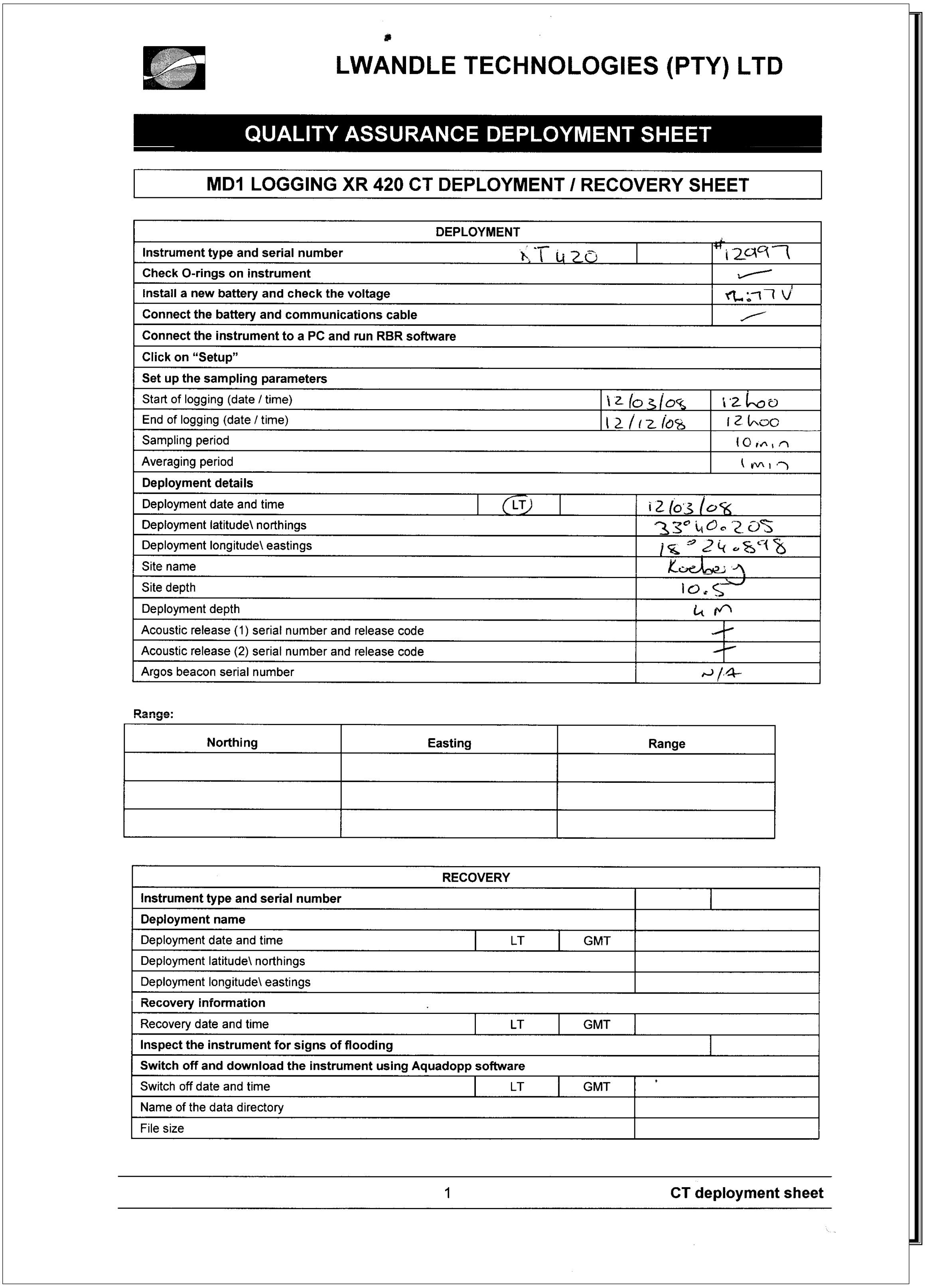
DEPLOYMENT			
Instrument type and serial number	XR 420 CT		#12999
Check O-rings on instrument			✓
Install a new battery and check the voltage			12.26
Connect the battery and communications cable			✓
Connect the instrument to a PC and run RBR software			✓
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		16/01/08	13h00
End of logging (date / time)		31/12/08	12h00
Sampling period			10 mins
Averaging period			1min
Deployment details			
Deployment date and time	[✓ LT]		12h06
Deployment latitude\ northings			33° 40.205
Deployment longitude\ eastings			18° 24.898
Site name			KOEBERG
Site depth			10.5 m
Deployment depth			10.5m
Acoustic release (1) serial number and release code			—
Acoustic release (2) serial number and release code			—
Argos beacon serial number			—

Range:

Northing	Easting	Range

RECOVERY			
Instrument type and serial number			
Deployment name			
Deployment date and time	LT	GMT	
Deployment latitude\ northings			
Deployment longitude\ eastings			
Recovery information			
Recovery date and time	LT	GMT	

1 **CT deployment sheet**



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

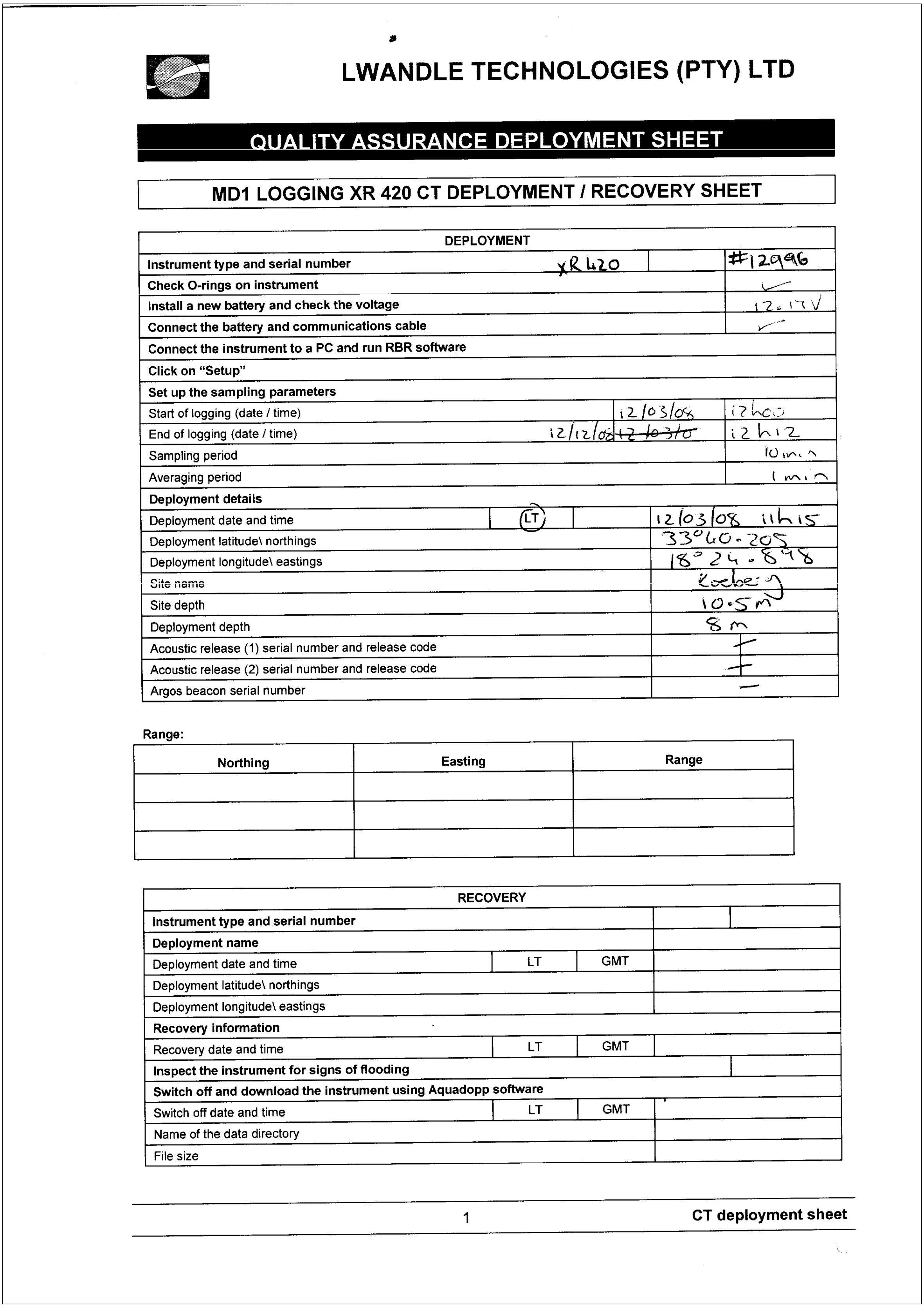
DEPLOYMENT			
Instrument type and serial number	XT420		#12997
Check O-rings on instrument			✓
Install a new battery and check the voltage			12.77V
Connect the battery and communications cable			✓
Connect the instrument to a PC and run RBR software			
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		12/03/08	12h00
End of logging (date / time)		12/12/08	12h00
Sampling period			10min
Averaging period			1min
Deployment details			
Deployment date and time	[✓ LT]		12/03/08
Deployment latitude\ northings			33°40.205
Deployment longitude\ eastings			18°24.898
Site name			Koeberg
Site depth			10.5
Deployment depth			4m
Acoustic release (1) serial number and release code			✗
Acoustic release (2) serial number and release code			✗
Argos beacon serial number			N/A

Range:

Northing	Easting	Range

RECOVERY			
Instrument type and serial number			
Deployment name			
Deployment date and time	LT	GMT	
Deployment latitude\ northings			
Deployment longitude\ eastings			
Recovery information			
Recovery date and time	LT	GMT	
Inspect the instrument for signs of flooding			
Switch off and download the instrument using Aquadopp software			
Switch off date and time	LT	GMT	
Name of the data directory			
File size			

1 **CT deployment sheet**



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

DEPLOYMENT			
Instrument type and serial number	xR420		#12996
Check O-rings on instrument			✓
Install a new battery and check the voltage			12.17V
Connect the battery and communications cable			✓
Connect the instrument to a PC and run RBR software			
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		12/03/08	12h00
End of logging (date / time)	12/12/08	~~12/03/0~~	12h12
Sampling period			10min
Averaging period			1min
Deployment details			
Deployment date and time	[✓ LT]		12/03/08 11h15
Deployment latitude\ northings			33°40.205
Deployment longitude\ eastings			18°24.898
Site name			Koeberg
Site depth			10.5m
Deployment depth			8 m
Acoustic release (1) serial number and release code			-
Acoustic release (2) serial number and release code			-
Argos beacon serial number			-

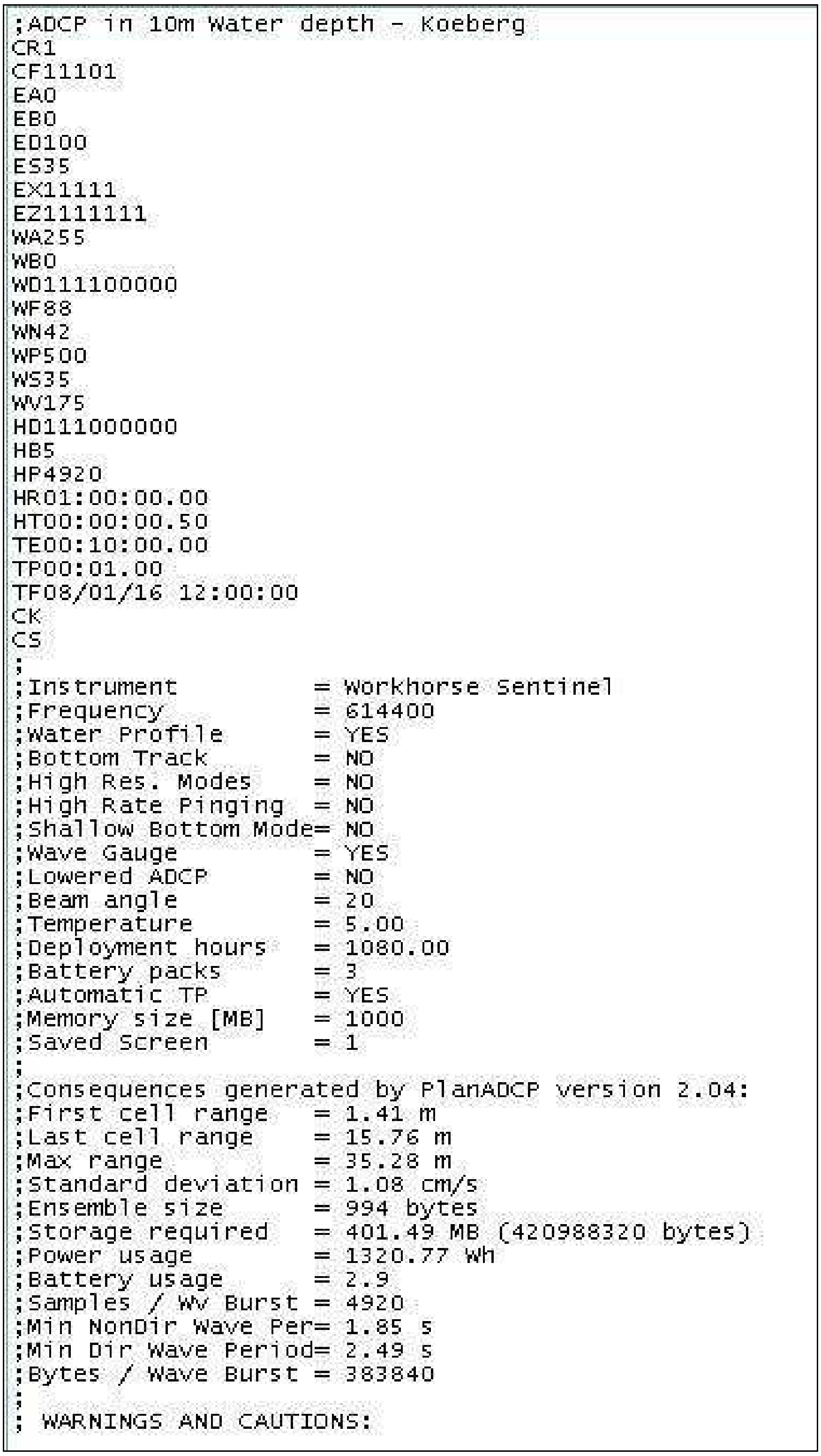
Range:

Northing	Easting	Range

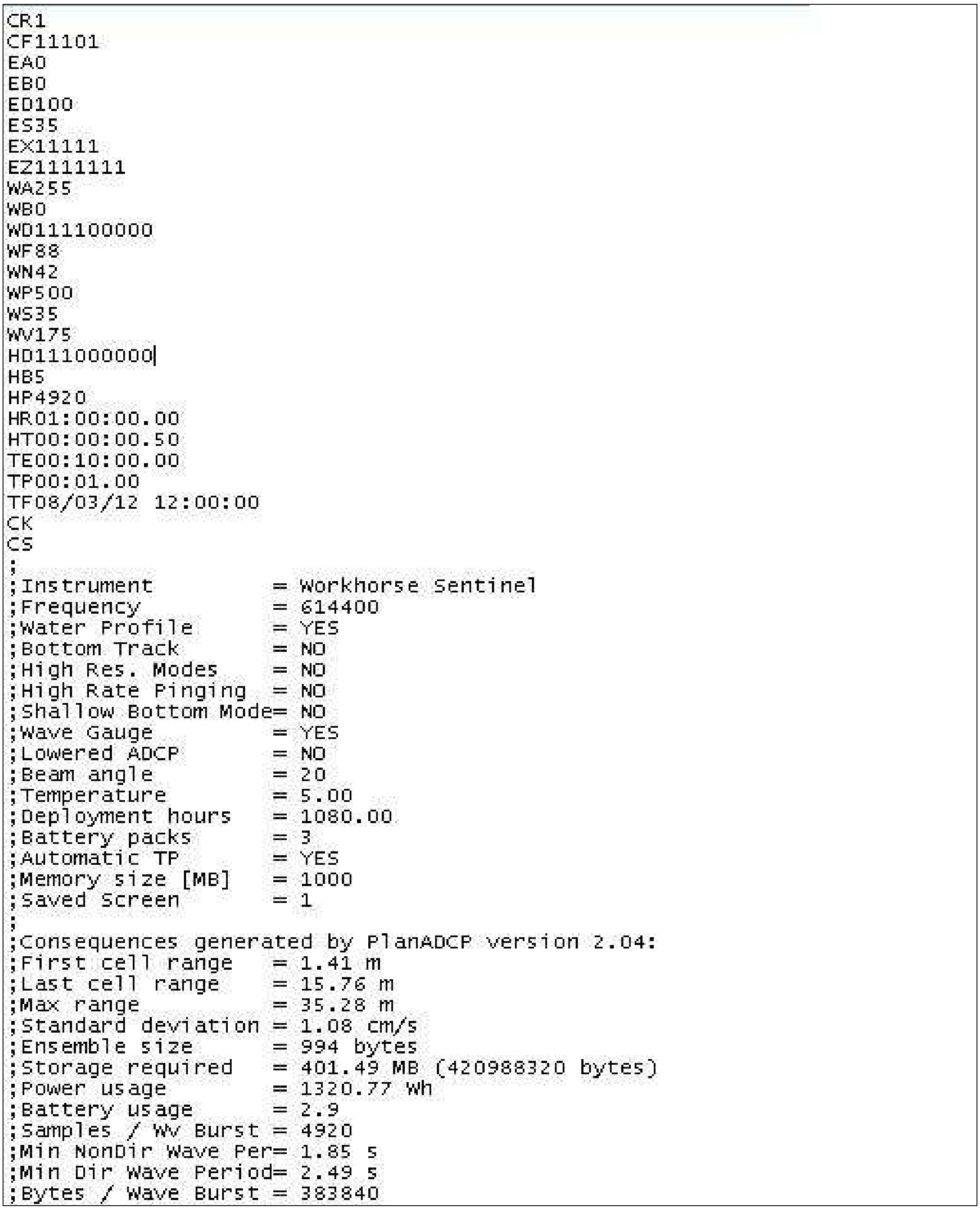
RECOVERY			
Instrument type and serial number			
Deployment name			
Deployment date and time	LT	GMT	
Deployment latitude\ northings			
Deployment longitude\ eastings			
Recovery information			
Recovery date and time	LT	GMT	
Inspect the instrument for signs of flooding			
Switch off and download the instrument using Aquadopp software			
Switch off date and time	LT	GMT	
Name of the data directory			
File size			

1 **CT deployment sheet**

7.3 ADCP CONFIGURATION FILES

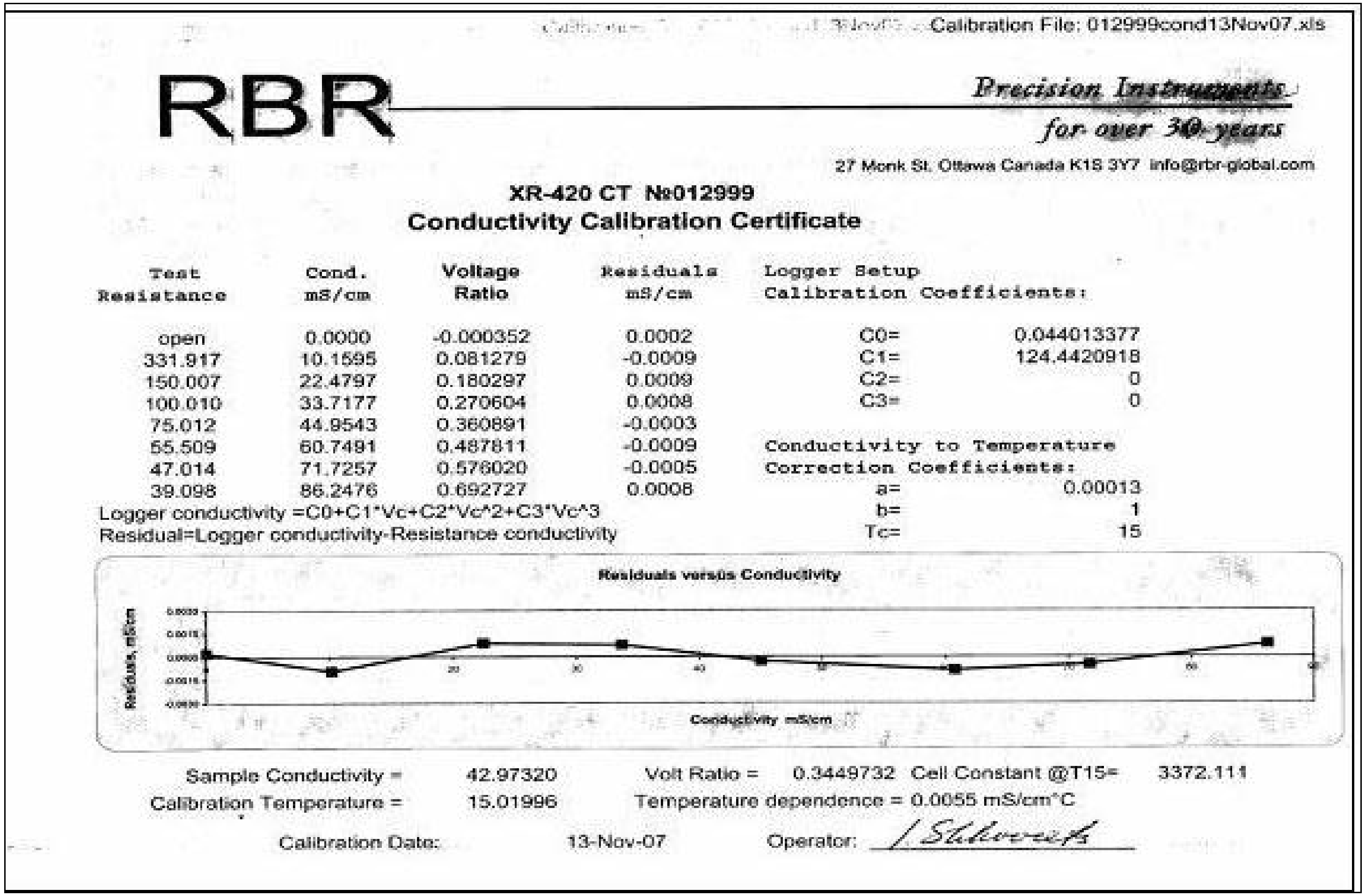


```
;ADCP in 10m Water depth - Koeberg
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:01.00
TF08/01/16 12:00:00
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 1080.00
;Battery packs       = 3
;Automatic TP        = YES
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 401.49 MB (420988320 bytes)
;Power usage         = 1320.77 Wh
;Battery usage       = 2.9
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
;
; WARNINGS AND CAUTIONS:
```



```
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:01.00
TF08/03/12 12:00:00
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 1080.00
;Battery packs       = 3
;Automatic TP        = YES
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 401.49 MB (420988320 bytes)
;Power usage         = 1320.77 Wh
;Battery usage       = 2.9
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
```

7.4 RBR-CT CALIBRATION CERTIFICATES



Calibration File: 012999cond13Nov07.xls

RBR

Precision Instruments for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012999

Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000352	0.0002
331.917	10.1595	0.081279	-0.0009
150.007	22.4797	0.180297	0.0009
100.010	33.7177	0.270604	0.0008
75.012	44.9543	0.360891	-0.0003
55.509	60.7491	0.487811	-0.0009
47.014	71.7257	0.576020	-0.0005
39.098	86.2476	0.692727	0.0008

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3

Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.044013377
C1= 124.4420918
C2= 0
C3= 0

Conductivity to Temperature
Correction Coefficients:

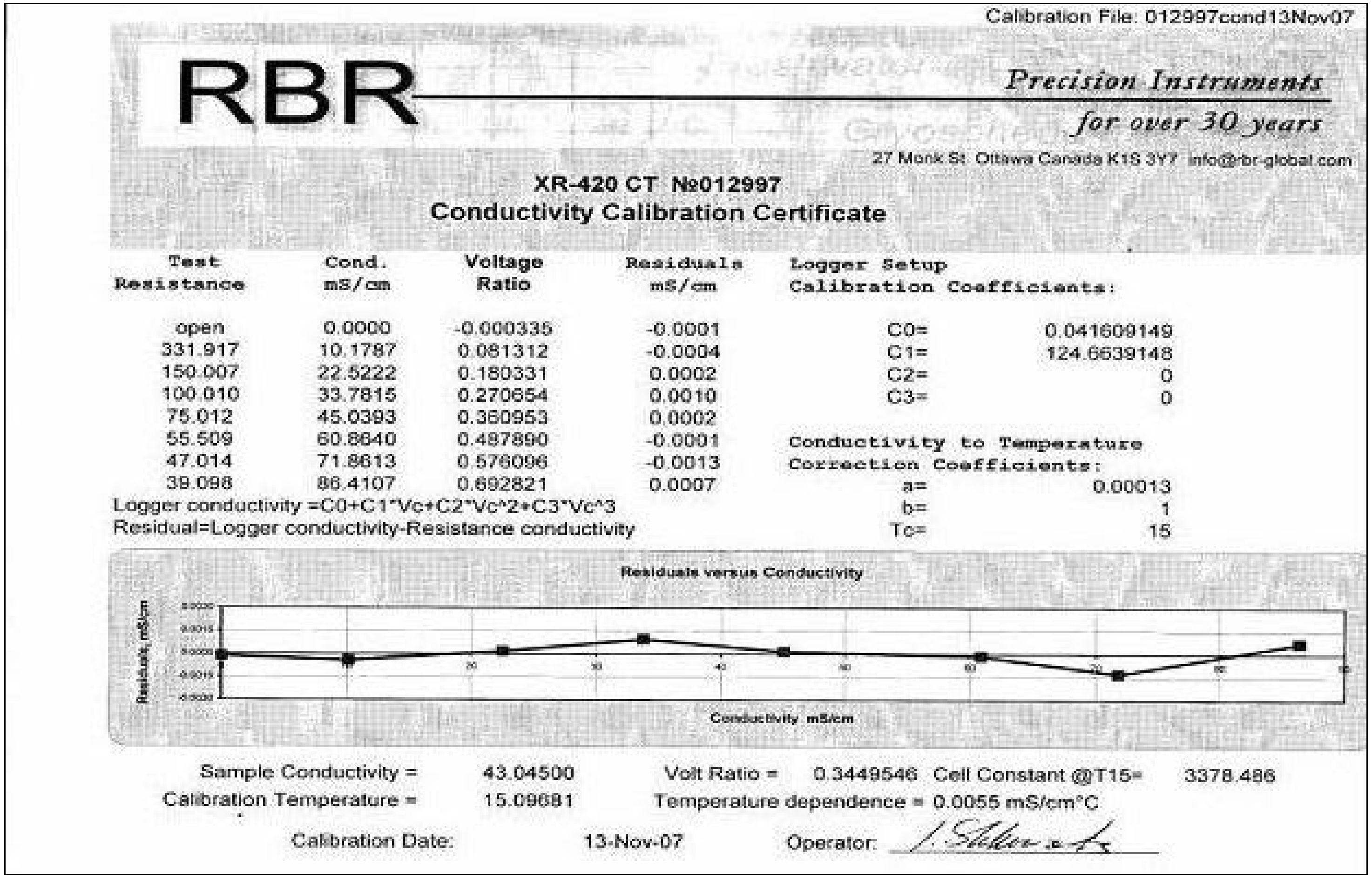
a= 0.00013
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 42.97320 Volt Ratio = 0.3449732 Cell Constant @T15= 3372.111

Calibration Temperature = 15.01996 Temperature dependence = 0.0055 mS/cm°C

Calibration Date: 13-Nov-07 Operator:



Calibration File: 012997cond13Nov07

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012997
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000335	-0.0001
331.917	10.1787	0.081312	-0.0004
150.007	22.5222	0.180331	0.0002
100.010	33.7815	0.270654	0.0010
75.012	45.0393	0.360953	0.0002
55.509	60.8640	0.487890	-0.0001
47.014	71.8613	0.576096	-0.0013
39.098	86.4107	0.692821	0.0007

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.041609149
C1= 124.6539148
C2= 0
C3= 0

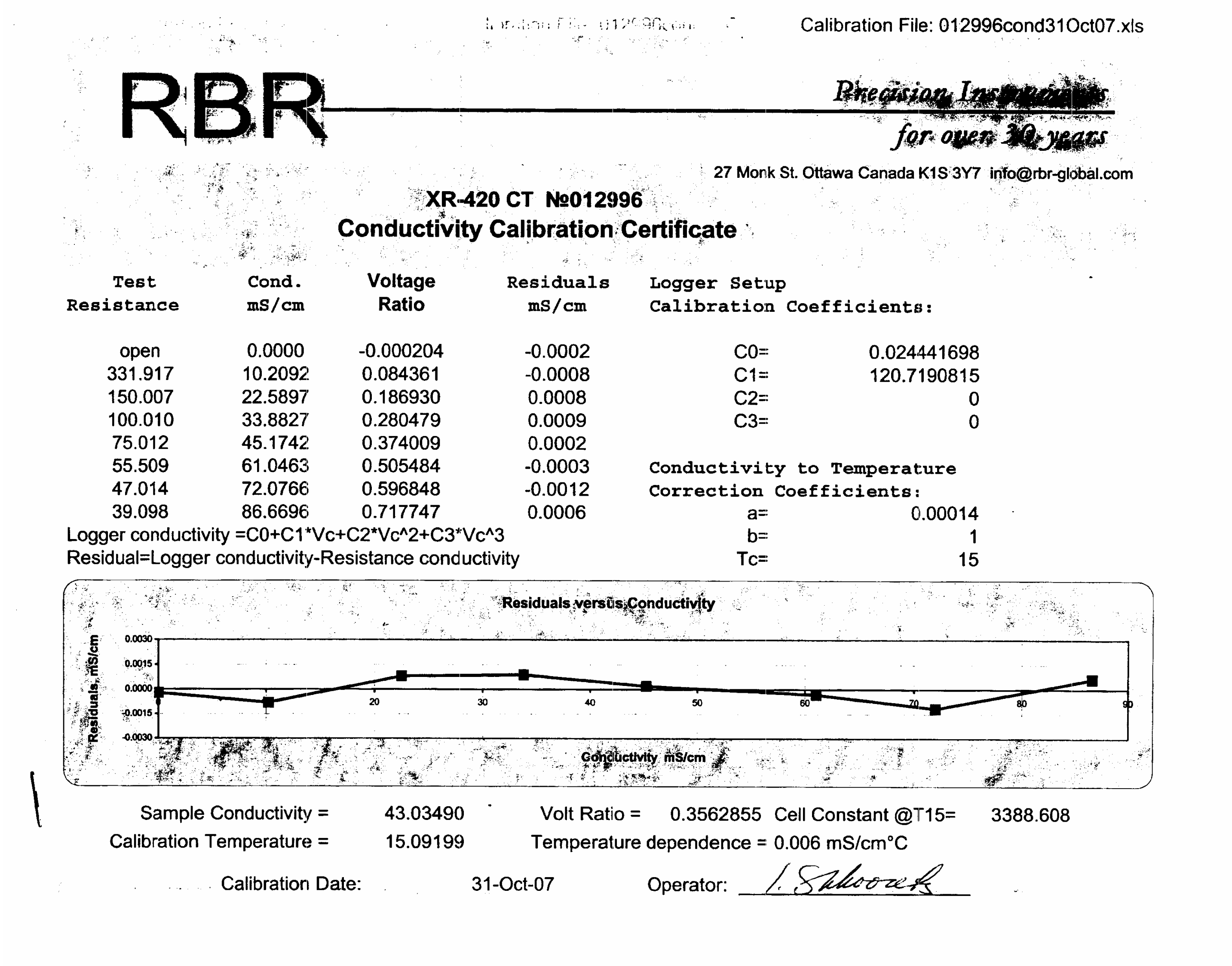
Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 43.04500 Volt Ratio = 0.3449546 Cell Constant @T15= 3378.486
Calibration Temperature = 15.09681 Temperature dependence = 0.0055 mS/cm°C

Calibration Date: 13-Nov-07 Operator:



Calibration File: 012996cond31Oct07.xls

RBR *Precision Instruments for over 30 years*

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012996
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000204	-0.0002
331.917	10.2092	0.084361	-0.0008
150.007	22.5897	0.186930	0.0008
100.010	33.8827	0.280479	0.0009
75.012	45.1742	0.374009	0.0002
55.509	61.0463	0.505484	-0.0003
47.014	72.0766	0.596848	-0.0012
39.098	86.6696	0.717747	0.0006

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3

Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.024441698
C1= 120.7190815
C2= 0
C3= 0

Conductivity to Temperature
Correction Coefficients:

a= 0.00014
b= 1
Tc= 15

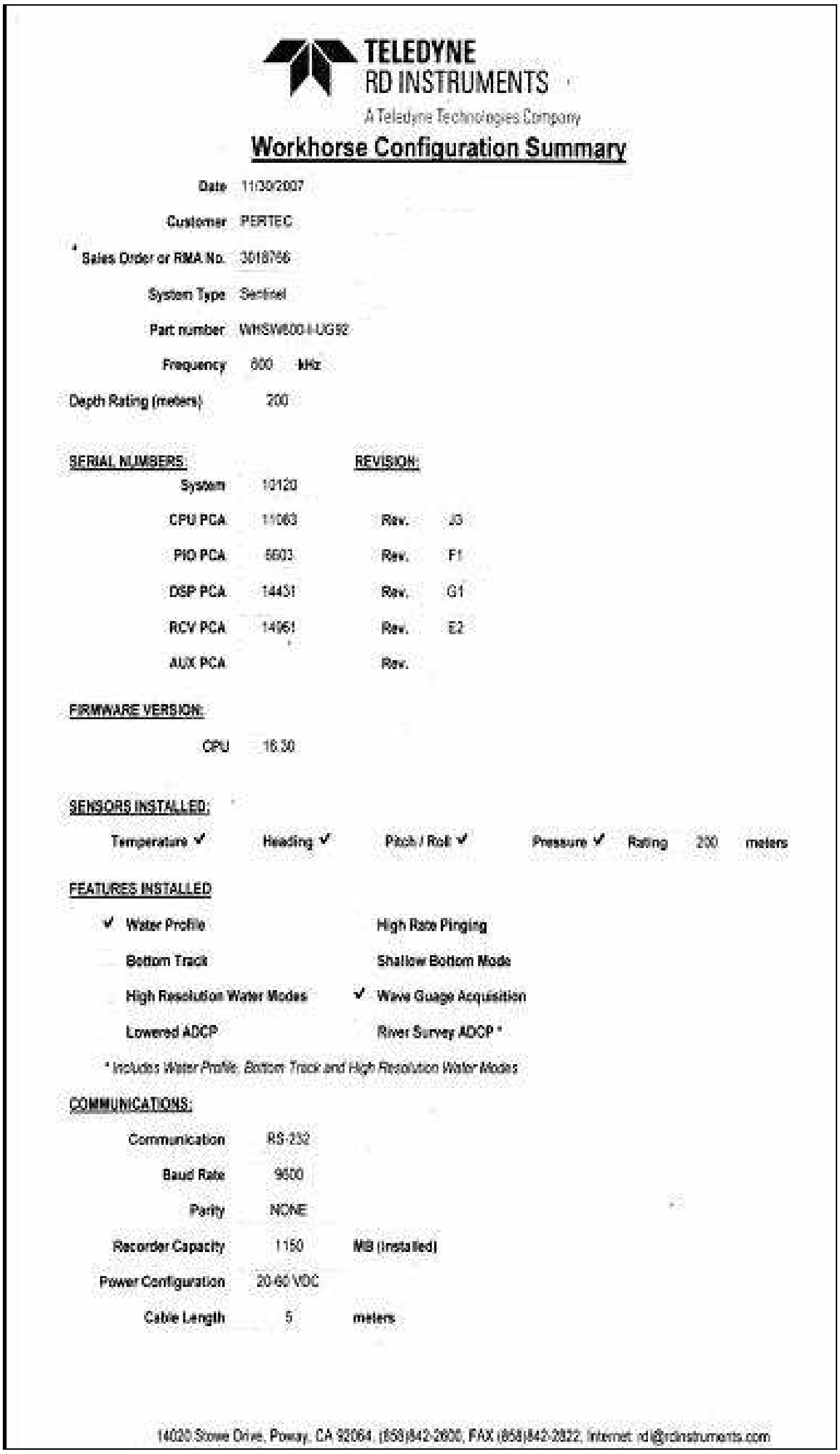
Residuals versus Conductivity

Sample Conductivity = 43.03490 Volt Ratio = 0.3562855 Cell Constant @T15= 3388.608

Calibration Temperature = 15.09199 Temperature dependence = 0.006 mS/cm°C

Calibration Date: 31-Oct-07 Operator:

7.5 TRDI ADCP CALIBRATION CERTIFICATE



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date	11/30/2007
Customer	PERTEC
Sales Order or RMA No.	3018766
System Type	Sentinel
Part number	WHSW600-I-UG92
Frequency	600 kHz
Depth Rating (meters)	200

SERIAL NUMBERS:		**REVISION:**	
System	10120		
CPU PCA	11063	Rev.	JG
PIO PCA	6603	Rev.	F1
DSP PCA	14431	Rev.	G1
RCV PCA	14961	Rev.	E2
AUX PCA		Rev.	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ Heading ✓ Pitch / Roll ✓ Pressure ✓ Rating 200 meters

FEATURES INSTALLED

✓ Water Profile	High Rate Pinging
Bottom Track	Shallow Bottom Mode
High Resolution Water Modes	✓ Wave Guage Acquisition
Lowered ADCP	River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication	RS-232	
Baud Rate	9600	
Parity	NONE	
Recorder Capacity	1150	MB (installed)
Power Configuration	20-60 VDC	
Cable Length	5	meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com

8. REPORTS FROM THE CSIR

The reports from the CSIR are attached as an appendage.

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT TWO

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

16 July 2008

Job No: LT-JOB-50

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 2 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-8.7	100	0.5388	0.0947	0.1072	0.0548	25.23
-8.3	100	0.5690	0.0971	0.112	0.0585	23.77
-8.0	100	0.5939	0.0991	0.1151	0.0619	22.00
-7.6	100	0.5966	0.1008	0.1183	0.0656	19.90
-7.3	100	0.6222	0.1039	0.1211	0.0696	17.01
-6.9	100	0.6385	0.1058	0.1238	0.0737	15.50
-6.6	99.97	0.6115	0.1083	0.1258	0.0769	13.95
-6.2	100	0.6222	0.1115	0.1281	0.0810	12.13
-5.9	100	0.6418	0.1160	0.1298	0.0862	10.19
-5.5	100	0.6531	0.1207	0.1315	0.0919	7.29
-5.2	100	0.6568	0.1257	0.1329	0.0966	5.07
-4.8	100	0.6585	0.1299	0.1347	0.1010	3.63
-4.5	100	0.6638	0.1343	0.1368	0.1057	1.97
-4.1	100	0.6726	0.1385	0.1387	0.1102	0.52
-3.8	100	0.6917	0.1427	0.1405	0.1144	358.81
-3.4	100	0.7105	0.1478	0.1425	0.1192	356.42
-3.1	100	0.7036	0.1519	0.1448	0.1236	355.05
-2.7	100	0.7124	0.1544	0.1466	0.1256	355.23
-2.4	100	0.7387	0.1546	0.1464	0.1232	359.80
-2.0	100	0.7133	0.1559	0.1446	0.122	5.32
-1.7	100	0.7318	0.1646	0.1436	0.1303	2.20
-1.3	99.36	0.7300	0.1712	0.1458	0.1464	350.19
-1.0	85.86	0.7627	0.1756	0.1417	0.1504	340.28

Table 2 – Waves summary

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	100	2.51	0.44	1.27	0.38
Tp (s)	100	19.60	2.00	12.13	1.76

Table 3 – Water temperature and salinity summary for surface RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^oC)	100	12.18	15.54	9.68
Conductivity	100	38.25	42.36	31.87
Salinity (psu)	100	33.12	35.12	27.84

Table 4 – Water temperature and salinity summary for bottom RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^oC)	100	11.64	15.48	9.64
Conductivity	100	34.85	40.67	25.86
Salinity (psu)	100	30.46	34.94	20.38

2. INTRODUCTION

2.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period March 12th 2008 - May 26th 2008 (Period 2) as well as sediment, water and grab samples collected during Service Visit 1 (May 26th – 29th 2008).

2.2 EQUIPMENT LIST

Lwandle provided the equipment as listed in Table 5 for the Koeberg site.

Table 5 – List of equipment provided.

Item	Operational (on site)	Spare (for whole project)
TRDI 600kHz ADCP	1	1
RBR XR420 CT logger	2	1

2.3 MEASUREMENT LOCATION

The initial deployment location of the mooring is shown in Figure 1.

Figure 1 - Map of the project area. The position of the deployed instrumentation is indicated by an icon on the left – 18° 24.897'E, 33° 40.206'S.

3. OPERATIONS

3.1 SUMMARY OF EVENTS

Service visit 2 was undertaken on May 26th – 29th 2008 and is detailed in Table 6.

Table 6 – Summary of events for Service Visit 2

Date	Description
26 May 2008 10h00	Lwandle's engineers met up with the dive support team at Koeberg Nuclear Power Station, South Breakwater entrance.
10h15	The engineers and divers loaded up the Lwandle vessel.
10h30	The vessel departed from Koeberg harbour and headed towards the mooring position.
10h45	The engineers marked the position of site with a shotline. The divers entered the water to locate the ADCP mooring using the circular sweep search technique. The divers released the T&C mooring line. They then proceeded to attach a lift bag to the frame, to lift it out of the sand to release the four sections of chain. The chains were detached from the frame and marked with the shotline. The ADCP frame was surfaced using the airlift bag.
12h30	The vessel returned to the harbor, to swop over the ADCP and download and service the RBR instrumentation.
13h00	A replacement cable for the external battery canister was needed before the equipment could be redeployed.
16h00	The Lwandle Engineers and divers headed back out to the mooring position.
16h30	The divers descended to re-attach the sections of chain to the ADCP frame,and to shackle the T&C mooring line in position.
17h15	The divers conducted 2 circular searches to look for the biofouling array, but no success.
17h45	The vessel returned to the harbour.
27 May 2008 09h00	The Lwandle engineers headed towards the mooring position to release the biofouling array via the acoustic release.
10h30	The biofouling array did not surface, although the acoustic release gave a positive release response. It was decided to get divers to conduct more searches.
15h00	The divers located the biofouling array and released it from the bottom mooring. No plates were intact on the line.
16h00 29 May 2008 13h00	The vessel returned to the harbour. The Biofouling mooring was redeployed at 33°40'12"S; 18°24'53"E about 40m from its original location.

3.2 INSTRUMENT CONFIGURATIONS

The as deployed instrumentation configurations are given in this section and completed deployment / recovery sheets are given as an appendix (Section 7, page 35) to this report.

3.2.1 600kHz ADCP

Table 7 – Instrument configuration for the ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	10120
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.35 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

Spare ADCP (s/n 10117) was redeployed.

3.2.2 RBR XR420 CT LOGGER

Table 8 – Instrument configuration for T&C Mooring Line.

Parameter	Configuration
XR 420 Temperature and Conductivity	s/n 12996 (3m) and s/n 12997 (8m)
Sampling and Averaging	Sample at 1Hz for 1 minute every 10 minutes

3.2.3 Biofouling Mooring

Table 9 – Instrument configuration for Biofouling Mooring Line.

Parameter	Configuration
Biofouling Plates	3 plates (50cmx50cm) at 3m and 3 plates (50cmx50cm) at 8m
Edgetech Acoustic Release	s/n 32385 release code 642102

The new plates are 20cm x 20cm (Photos attached, Figure 21).

RECOVER AND REDEPLOYMENT METHODOLOGY

3.2.4 T&C mooring

The T&C mooring line was deployed by lowering the array down via a rope through the anchor weights. The mooring line is recovered using divers to undo a single shackle that connects the mooring line to the anchor weights. Divers reattach the line onto the weights, after the instruments have been serviced.

3.2.5 ADCP mooring

The ADCP Frame is lowered to the bottom and moved into position by divers, who also attach chain sections that act as anchors. To retrieve the frame divers have to locate the mooring, take off the anchor chains and surface the frame using air lift bags that they attach.

Figure 2 – ADCP frame with 600KHz instrument.

3.2.6 Biofouling mooring

The biofouling mooring line was deployed by lowering the array down via a rope through the anchor weights. Divers would locate the mooring line and retrieve a surface and bottom plate from the line at the required sampling periods.

3.3 MALFUNCTIONS AND LESSONS LEARNT

A list of malfunctions experienced and consequent measures to be taken in future are provided in Table 10.

Table 10 – Lessons learnt and future mitigation measures

Malfunction	Future action(s)
Power cable from ADCP to external battery canister was chafing due to sand build up around mooring	Cover cable in protective tape and cable wrap.*
No plates to recover on the biofouling mooring	Use smaller (20cm x 20cm) plates, which will offer less resistance and strengthen them with a plastic backing.
The acoustic release on the biofouling mooring was buried in sand and had growth on the release mechanism	Use a longer anchor chain and paint release mechanism with anti-fouling paint, rather that silicone grease.

*A slightly modified ADCP frame is going to be used at all sites. Plinths weighing 450kg have been ordered and the new frames with inline gimbals will allow the engineers to setup the ADCP and external battery canister in a way to minimise the length of the connecting cables.

4. DATA QUALITY CONTROL

4.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

4.1.1 Current processing

- The record was truncated to exclude times pre and post deployment.
- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 11’ W.
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP’s pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of 0.2ms^{-1} was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined. These sensors were within their operating range (Figure 3).
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

4.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 11' W.
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

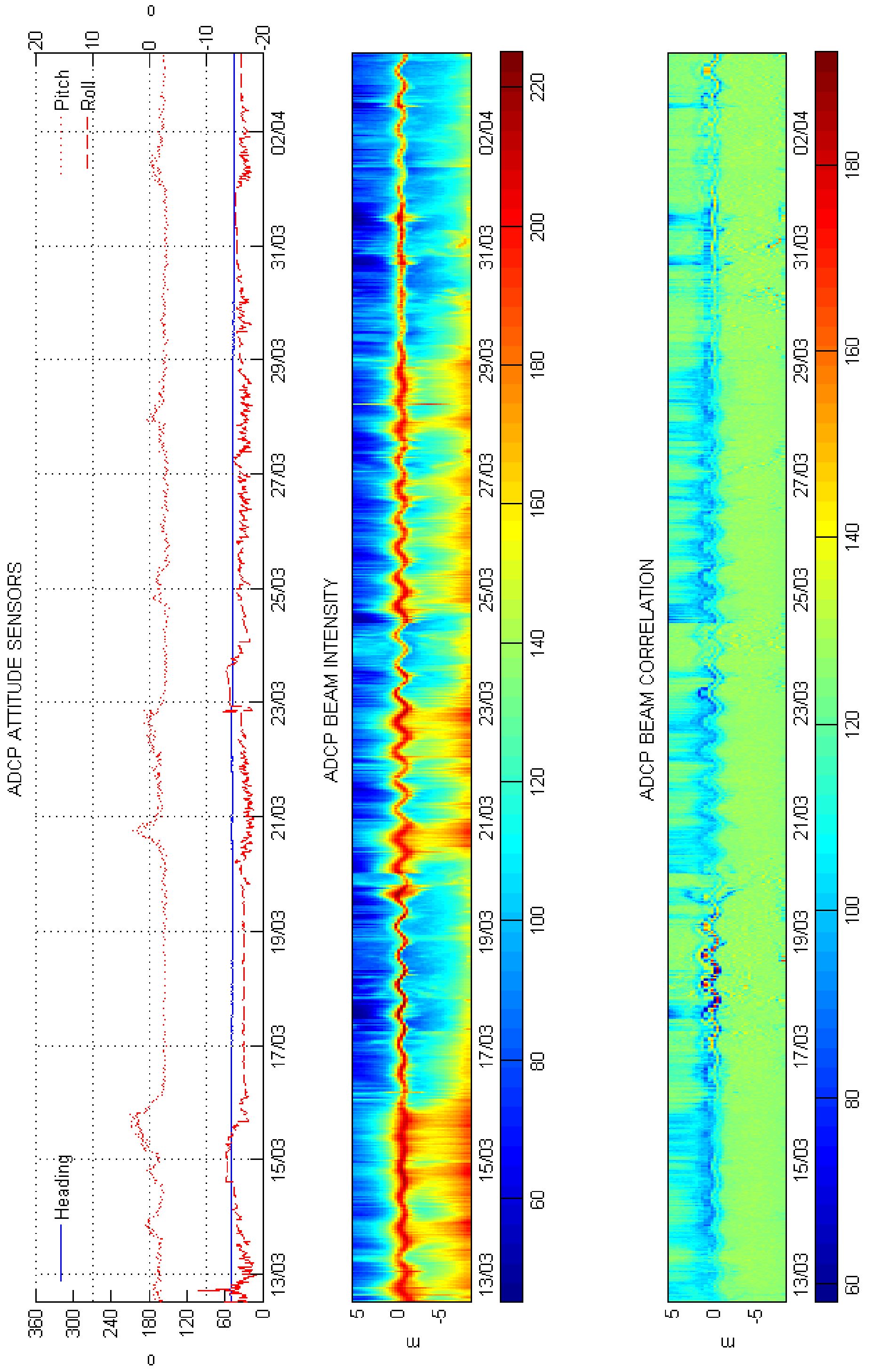


Figure 3: Quality control data from the ADCP. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

4.2 RBR-CT LOGGER

The conductivity and temperature data were exported directly from the RBR software into Matlab for further processing.

- The record was truncated to exclude times pre and post deployment.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.

4.3 BIOFOULING.

The following standard procedure is normally followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates are measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 CaC03 chips are added.
- Sample bottles are stored upright in the dark.

Recovery of the biofouling plates was scheduled for service visit 2. However, the plates were lost. Recovery of the new plates is now scheduled in three months, where two plates (surface (3m) and bottom (8m)) will be collected.

5. DATA PRESENTATION

All data presented have been subject to the quality control procedures detailed in the previous section. Bad data have been excluded from all plots and calculations.

All plots in this section include a stamp that details the location, depth, time period and number of observations that the plot is based upon. Wherever possible, scaling of parameters has been kept constant throughout this section to facilitate comparison between plots and stations.

5.1 ADCP

5.1.1 Current Data

5.1.1.1 Time series plot

The figures on the following pages display time series plots for depths of 8.7m, 4.8m and 1.0m, representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

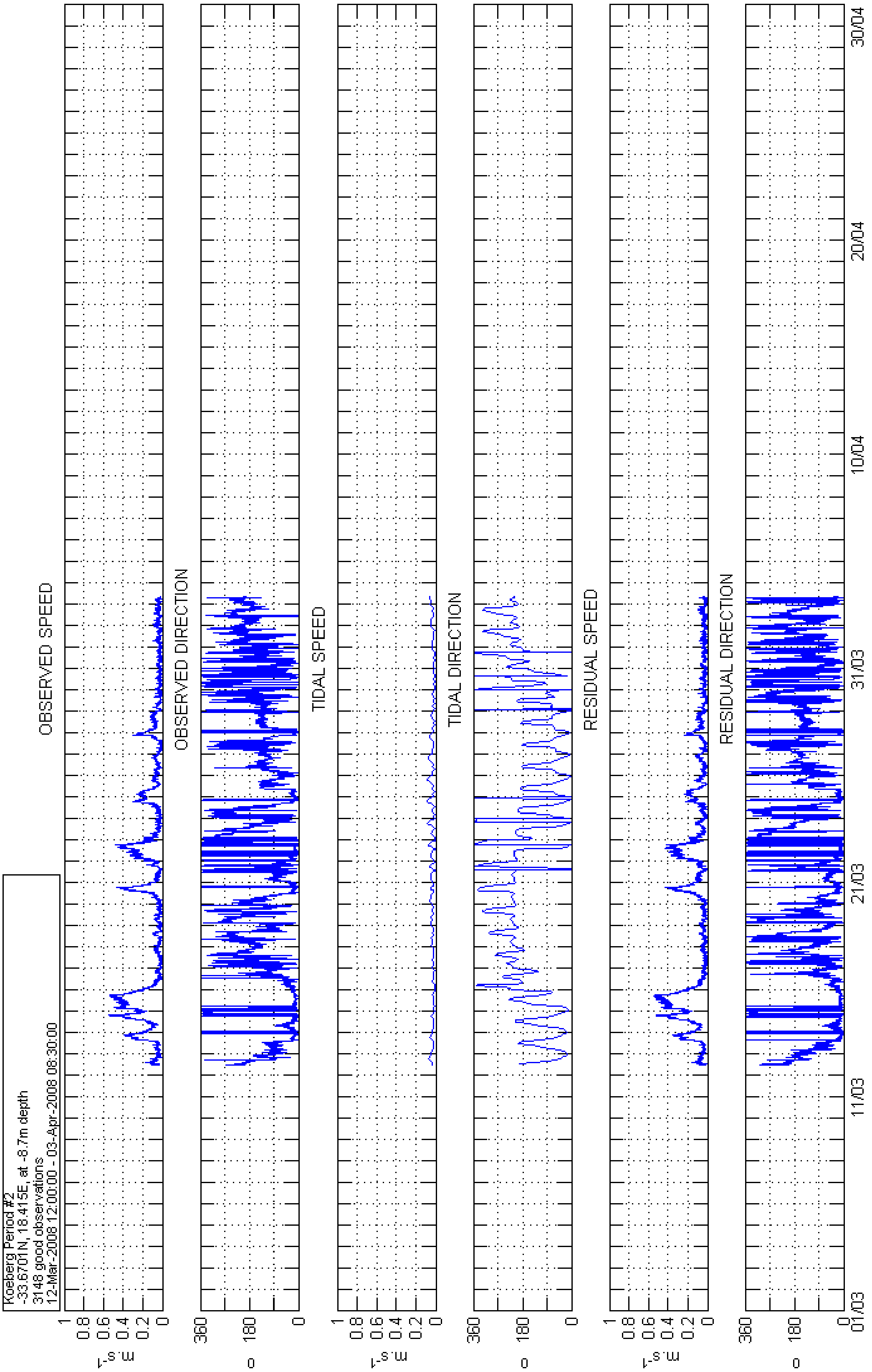


Figure 4: Time series plot of the ADCP's current data at 8.7m.

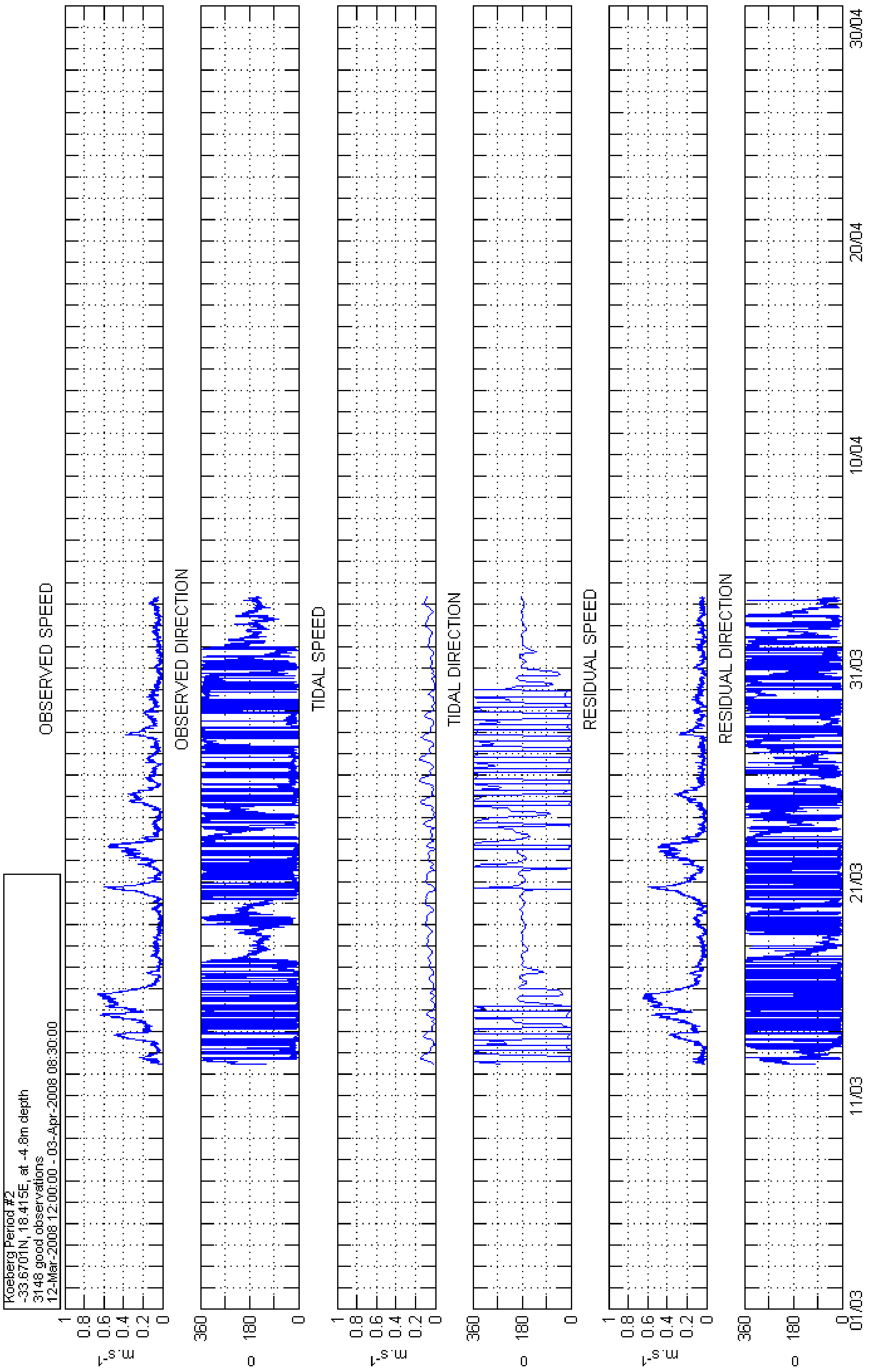


Figure 5: Time series plot of the ADCP's current data at 4.8m.

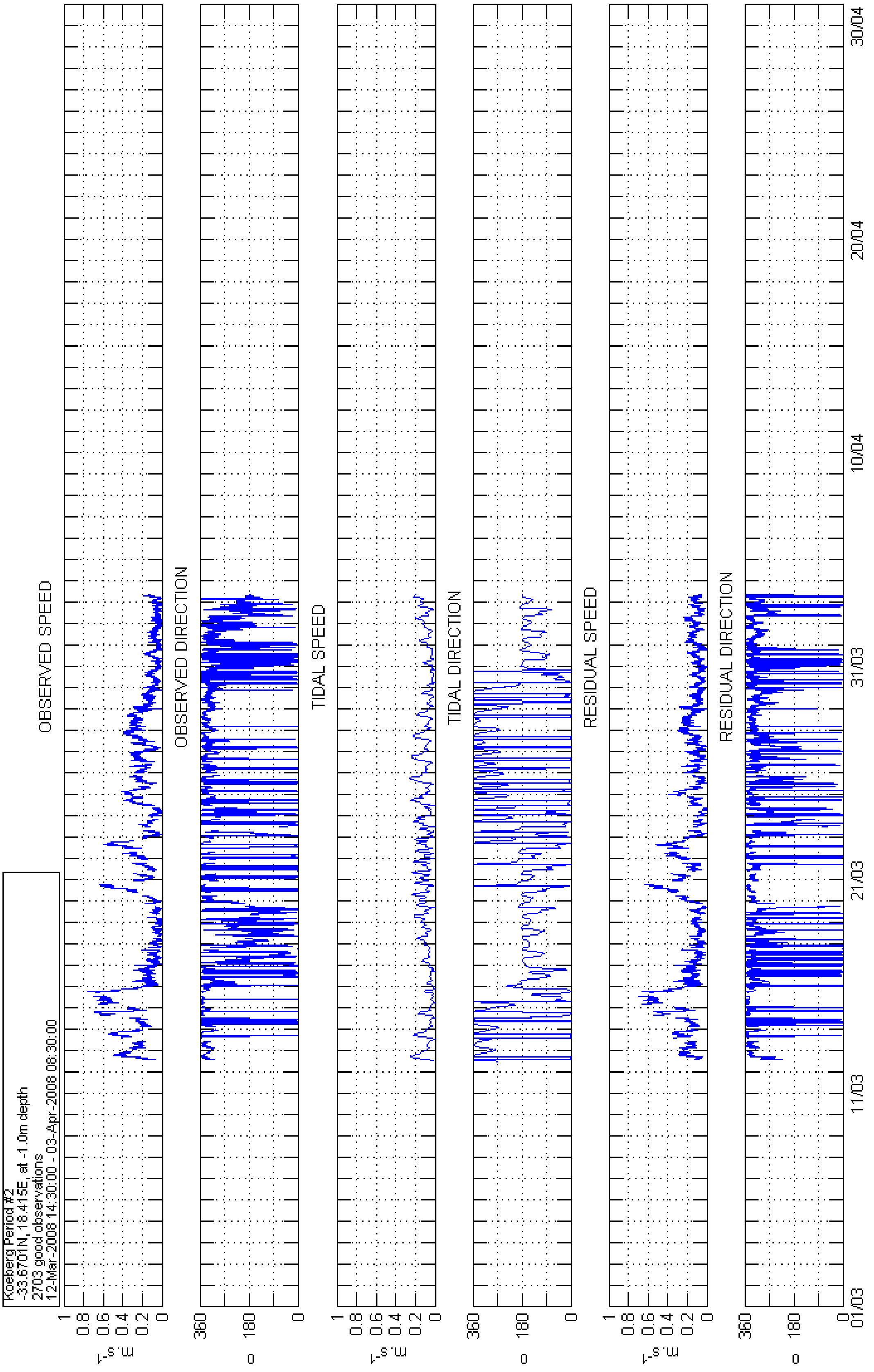


Figure 6: Time series plot of the ADCP's current data at 1.0m.

5.1.1.2 Summary plot

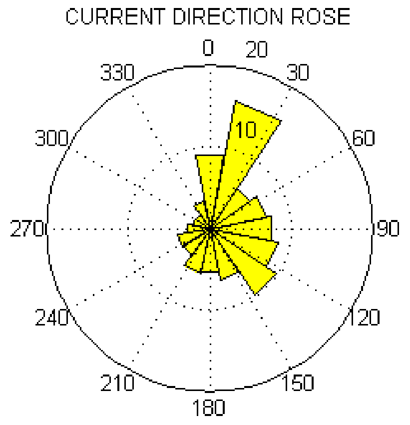
The figures on the following pages display summary plots for depths of 8.7m, 4.8m and 1.0m, representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg Period #2
-33.6701N, 18.415E, at -8.7m depth
3148 good observations
12-Mar-2008 12:00:00 - 03-Apr-2008 08:30:00

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	1.78	2.92	4.96	6.70	7.56	8.26	9.31	6.29	5.34	5.34	3.78	4.00	2.86	2.16	1.97	1.78	75.00
0.1-0.2	1.78	4.35	0.89	0.32	0.22	0.19	0.60	0.13	0.19	0.22	0.13	0.10			0.06	0.70	9.88
0.2-0.3	2.64	3.97	0.03												0.03	0.60	7.27
0.3-0.4	1.65	2.86														0.22	4.73
0.4-0.5	1.27	1.59															2.86
0.5-0.6	0.10	0.16															0.25
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	9.21	15.85	5.88	7.02	7.78	8.45	9.91	6.42	5.53	5.56	3.91	4.10	2.86	2.16	2.06	3.30	100.00



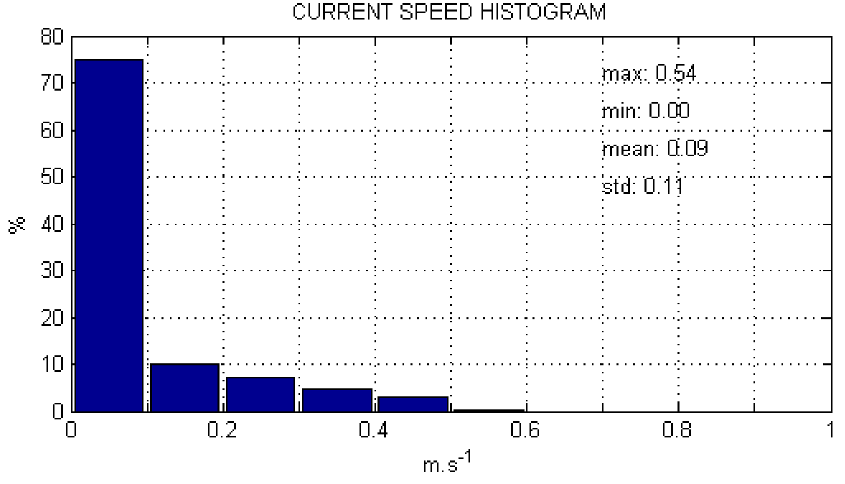


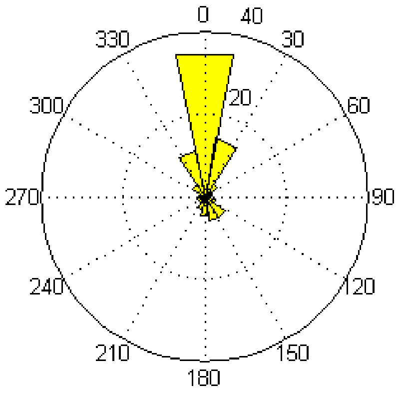
Figure 7: Summary plot of the ADCP's current data at 8.7m.

Koeberg Period #2
-33.6701N, 18.415E, at -4.8m depth
3148 good observations
12-Mar-2008 12:00:00 - 03-Apr-2008 08:30:00

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	9.72	8.42	3.40	1.97	1.43	2.54	5.46	5.62	4.54	2.86	1.91	1.49	1.11	1.37	3.02	6.96	61.82
0.1-0.2	9.28	4.92	0.32				0.57	0.29	0.13	0.13		0.16		0.06	0.35	3.02	19.22
0.2-0.3	5.15	0.70													0.10	0.86	6.80
0.3-0.4	4.13	0.35														0.38	4.86
0.4-0.5	3.24	0.06														0.16	3.46
0.5-0.6	3.18															0.06	3.24
0.6-0.7	0.60																0.60
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	35.29	14.45	3.72	1.97	1.43	2.54	6.04	5.91	4.67	2.99	1.91	1.65	1.11	1.43	3.46	11.44	100.00

CURRENT DIRECTION ROSE



CURRENT SPEED HISTOGRAM

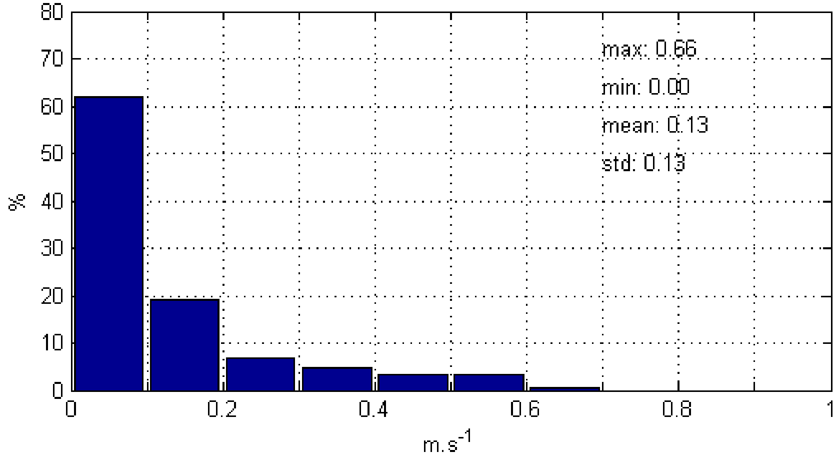


Figure 8: Summary plot of the ADCP's current data at 4.8m.

Koeberg Period #2
-33.6701N, 18.415E, at -1.0m depth
2703 good observations
12-Mar-2008 14:30:00 - 03-Apr-2008 08:30:00

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	3.92	2.48	1.00	1.33	0.81	1.04	1.37	2.15	2.85	2.63	1.81	2.00	2.00	3.18	5.25	4.88	38.70
0.1-0.2	5.51	1.66	0.52	0.22	0.15	0.04		0.15	0.37	0.22	0.26	0.33	0.26	1.04	6.14	8.58	25.45
0.2-0.3	4.74	0.37											0.07	1.11	4.29	9.58	20.16
0.3-0.4	2.52	0.15												0.18	1.18	3.88	7.92
0.4-0.5	1.41	0.04													0.15	1.18	2.77
0.5-0.6	2.37															1.22	3.59
0.6-0.7	1.04															0.26	1.29
0.7-0.8	0.04															0.07	0.11
0.8-0.9																	0.00
0.9-1																	0.00
Σ	21.53	4.70	1.52	1.55	0.96	1.07	1.37	2.29	3.22	2.85	2.07	2.33	2.33	5.51	17.02	29.67	100.00

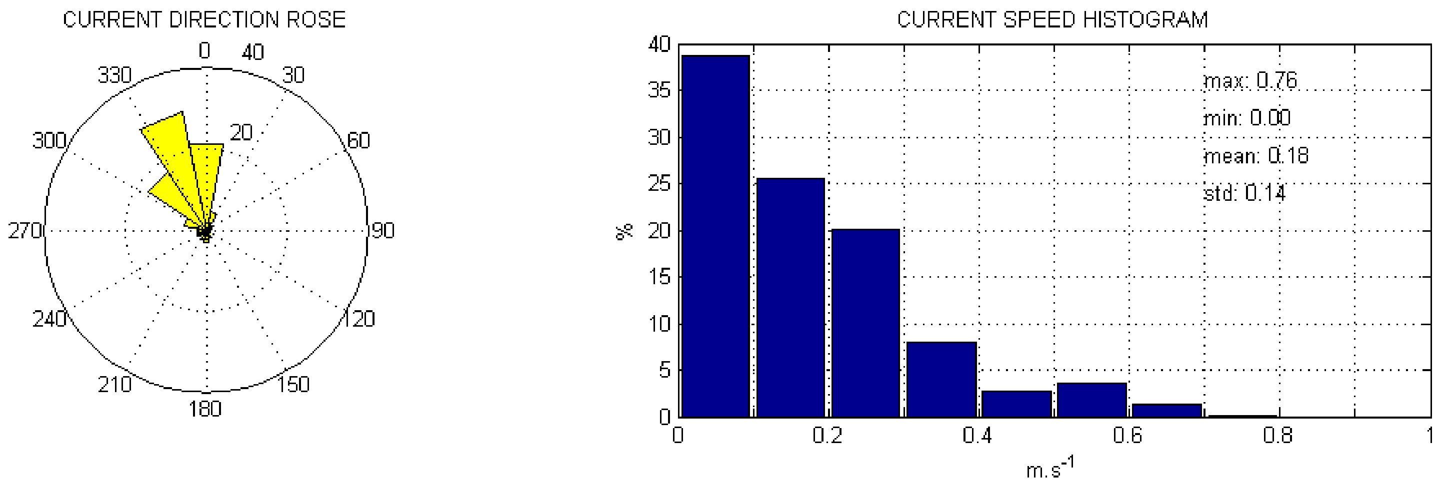


Figure 9: Summary plot of the ADCP's current data at 1.0m.

5.1.1.3 Progressive vector plot

Figure 10, Figure 11 and Figure 12 display progressive vector plots for depths of 8.7m, 4.8m and 1.0m, representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

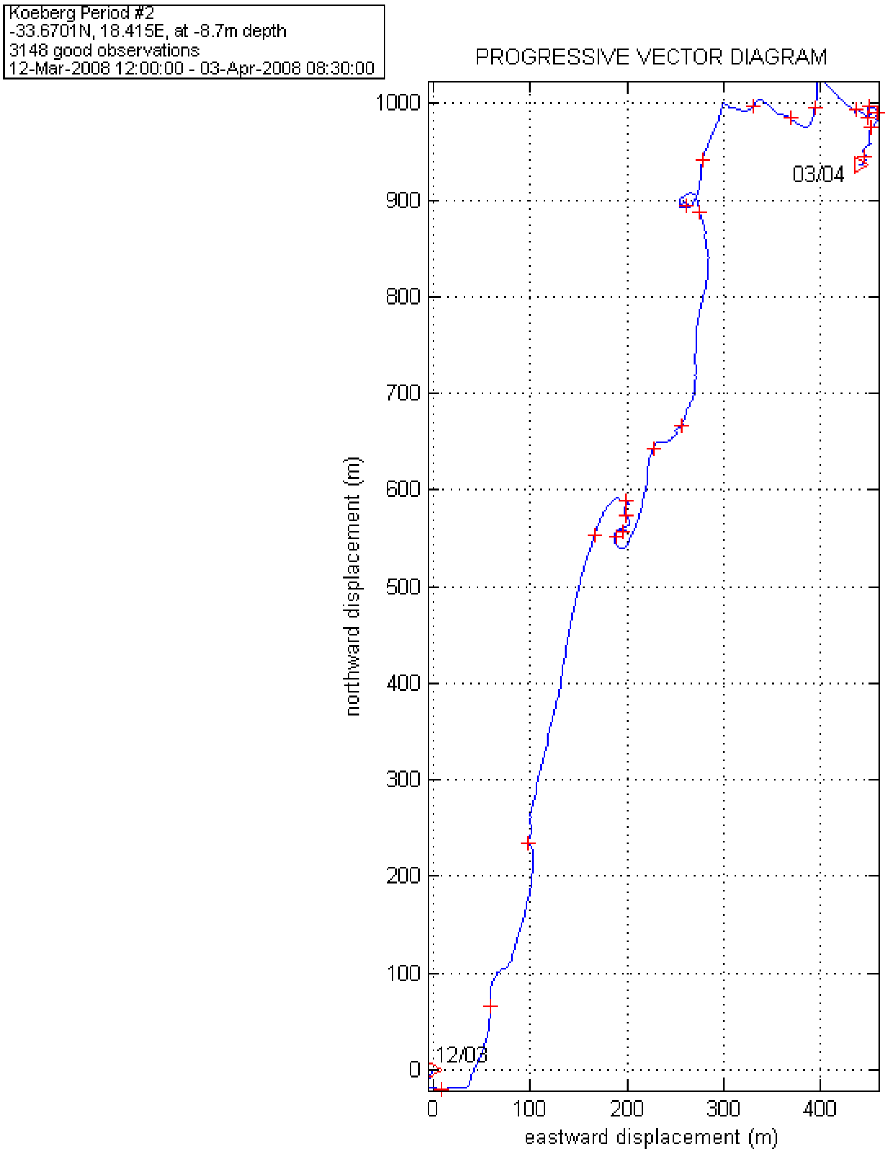


Figure 10: Progressive vector plot of current data at 8.7m.

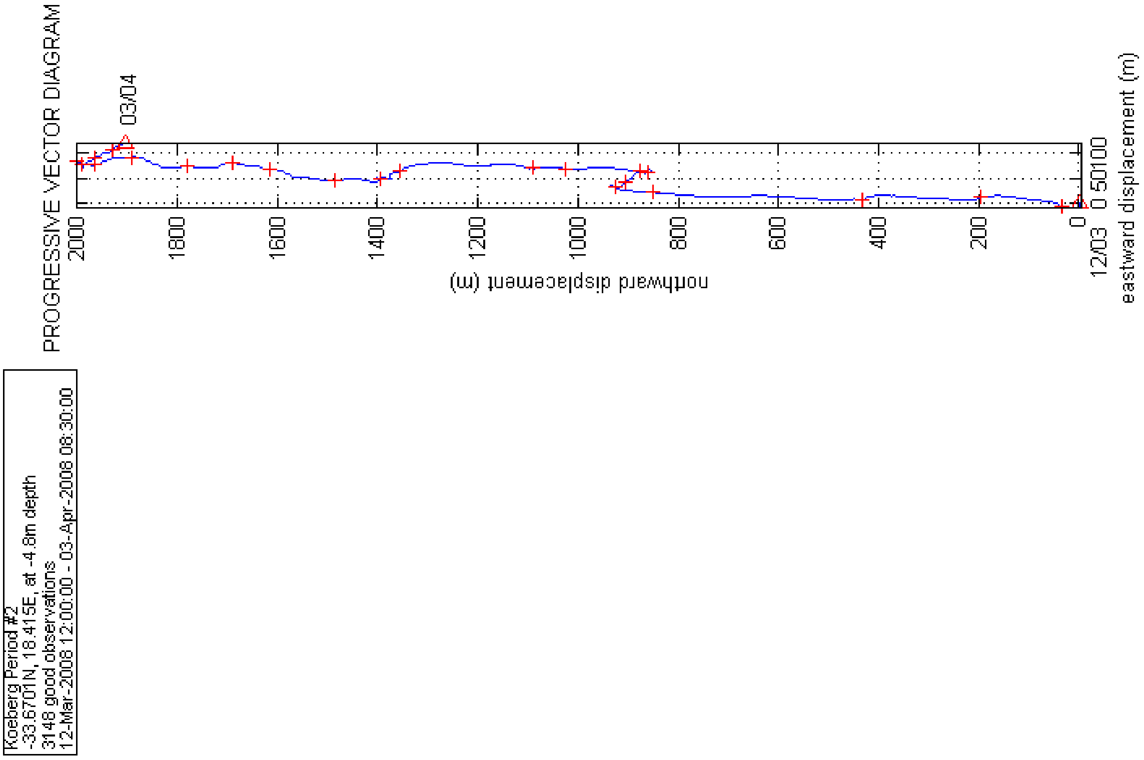


Figure 11: Progressive vector plot of current data at 4.8m.

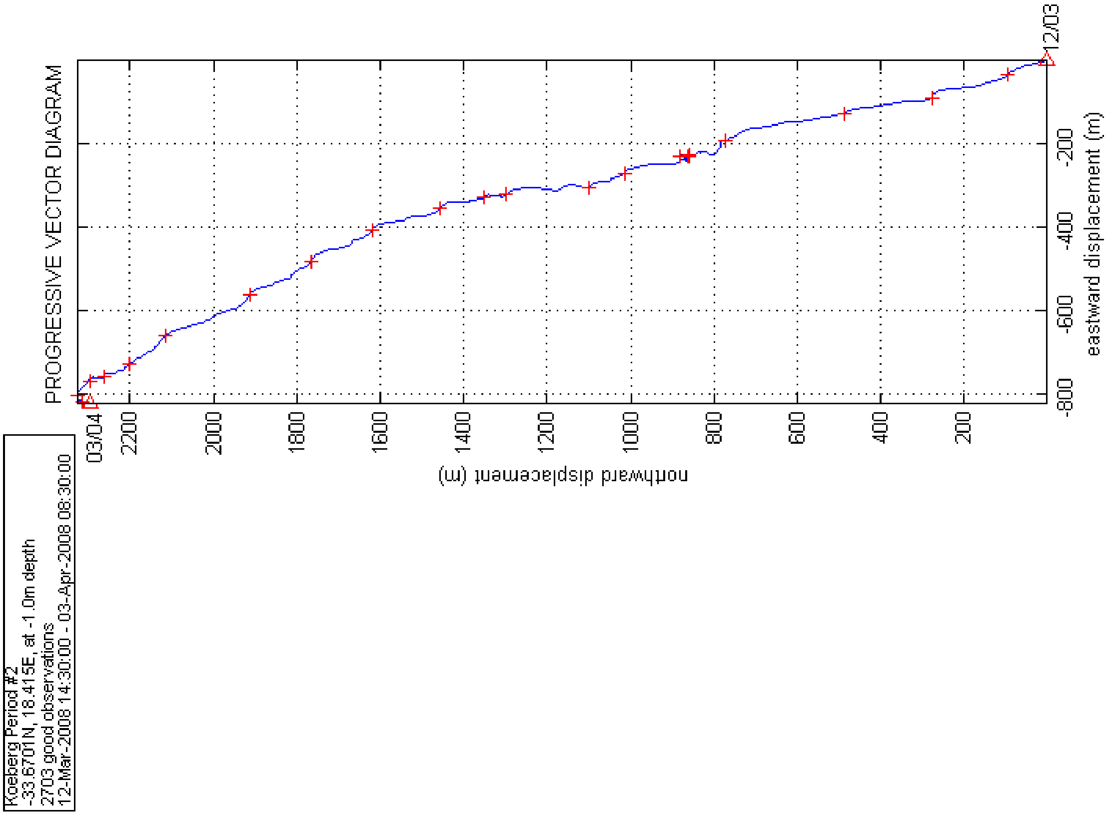


Figure 12: Progressive vector plot of current data at 1.0m.

5.1.2 Wave Data.

5.1.2.1 Time series plot

Figure 13 displays a time series plot of the main wave parameters:

- The first (upper) panel is of the significant wave height (Hs).
- The second panel is of the peak period (Tp).
- The third panel is of the peak wave direction (Dp).

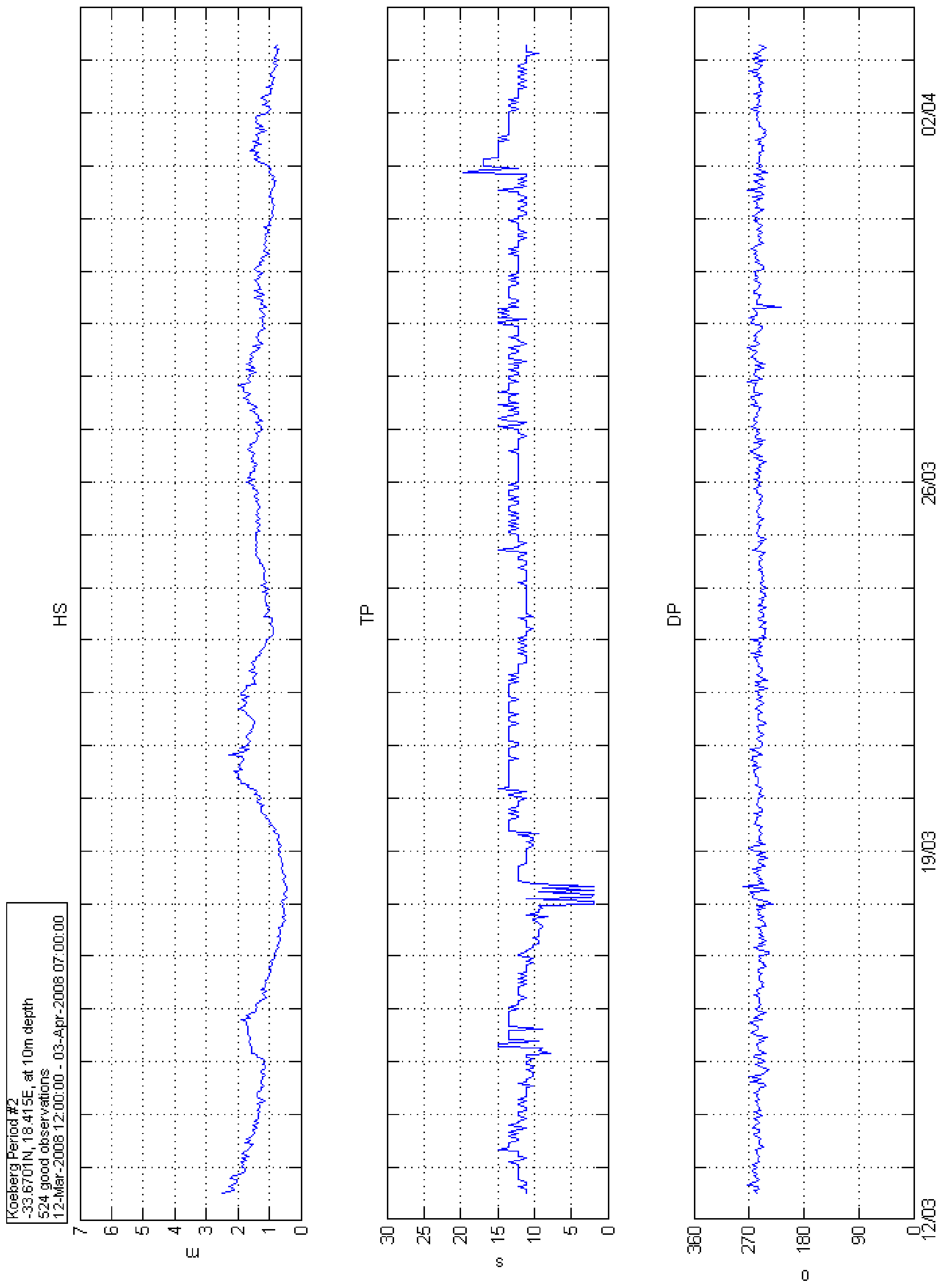


Figure 13: Times series of H_s, T_p and D_p.

5.1.2.2 Hs and Tp summary plot

Figure 14 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.1.2.3 Hs and Dp summary plot

Figure 15 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.1.2.4 Tp and Dp summary plot

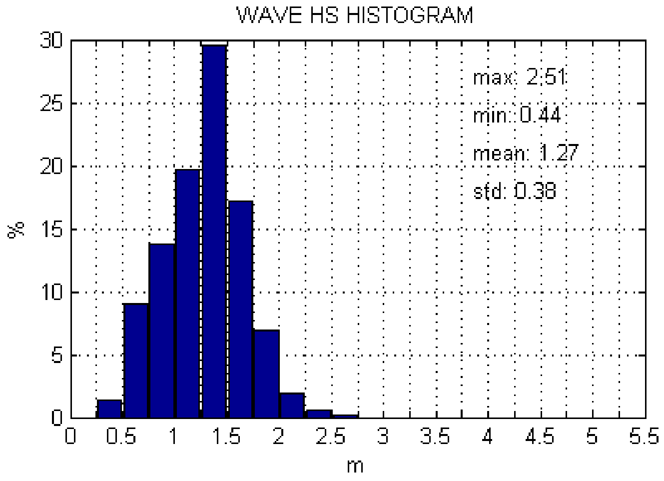
Figure 16 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

Koeberg Period #2
-33.6701N, 18.415E, at 10m depth
524 good observations
12-Mar-2008 12:00:00 - 03-Apr-2008 07:00:00

JOINT DISTRIBUTION OF HS AND TP

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5		0.57			0.38	0.38										1.34
0.5-0.75		0.57			2.86	3.82	1.72									8.97
0.75-1					0.19	7.06	6.11	0.19	0.19							13.74
1-1.25						8.40	10.11	0.57	0.38	0.19						19.66
1.25-1.5						5.15	21.76	2.29	0.38							29.58
1.5-1.75				0.19	0.76	0.38	14.50	1.34								17.18
1.75-2						0.19	6.49	0.19								6.87
2-2.25						0.76	1.15									1.91
2.25-2.5							0.57									0.57
2.5-2.75						0.19										0.19
2.75-3																0.00
3-3.25																0.00
3.25-3.5																0.00
3.5-3.75																0.00
3.75-4																0.00
4-4.25																0.00
4.25-4.5																0.00
4.5-4.75																0.00
4.75-5																0.00
5-5.25																0.00
5.25-5.5																0.00
Σ	0.00	1.15	0.00	0.19	4.20	26.34	62.40	4.58	0.95	0.19	0.00	0.00	0.00	0.00	0.00	100.00



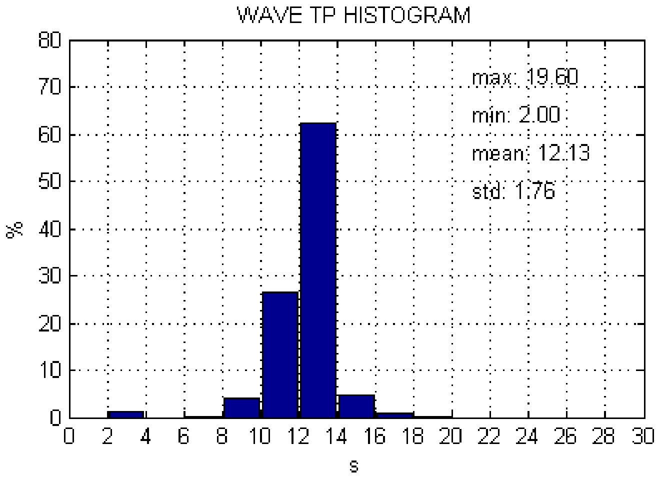


Figure 14: Summary plot of H_s and T_p.

Koeberg Period #2
-33.6701N, 18.415E, at 10m depth
524 good observations
12-Mar-2008 12:00:00 - 03-Apr-2008 07:00:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5												0.76	0.57				1.34
0.5-0.75											0.19	6.87	1.91				8.97
0.75-1												10.88	2.86				13.74
1-1.25											0.19	16.41	3.05				19.66
1.25-1.5												22.52	7.06				29.58
1.5-1.75												12.02	5.15				17.18
1.75-2												3.63	3.24				6.87
2-2.25												0.76	1.15				1.91
2.25-2.5												0.57					0.57
2.5-2.75												0.19					0.19
2.75-3																	0.00
3-3.25																	0.00
3.25-3.5																	0.00
3.5-3.75																	0.00
3.75-4																	0.00
4-4.25																	0.00
4.25-4.5																	0.00
4.5-4.75																	0.00
4.75-5																	0.00
5-5.25																	0.00
5.25-5.5																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	74.62	25.00	0.00	0.00	0.00	100.00

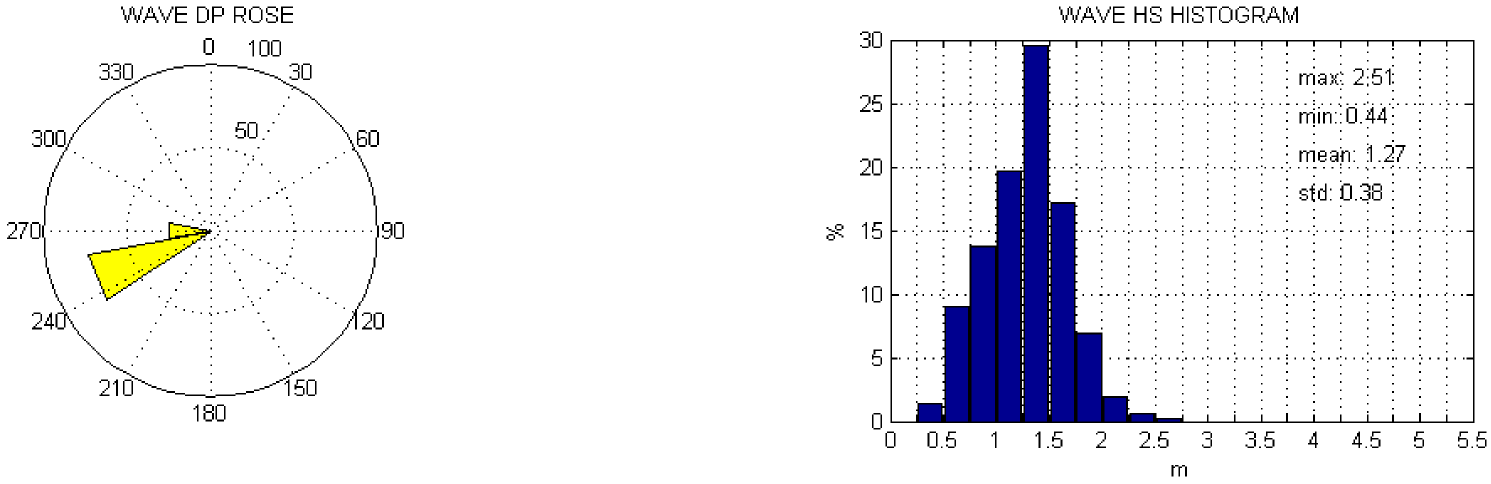


Figure 15: Summary plot of H_s and D_p.

Koeberg Period #2
-33.6701N, 18.415E, at 10m depth
524 good observations
12-Mar-2008 12:00:00 - 03-Apr-2008 07:00:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4											0.19	0.38	0.57				1.15
4-6																	0.00
6-8												0.19					0.19
8-10												3.63	0.57				4.20
10-12												21.18	5.15				26.34
12-14											0.19	45.61	16.60				62.40
14-16												2.48	2.10				4.58
16-18												0.95					0.95
18-20												0.19					0.19
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	74.62	25.00	0.00	0.00	0.00	100.00

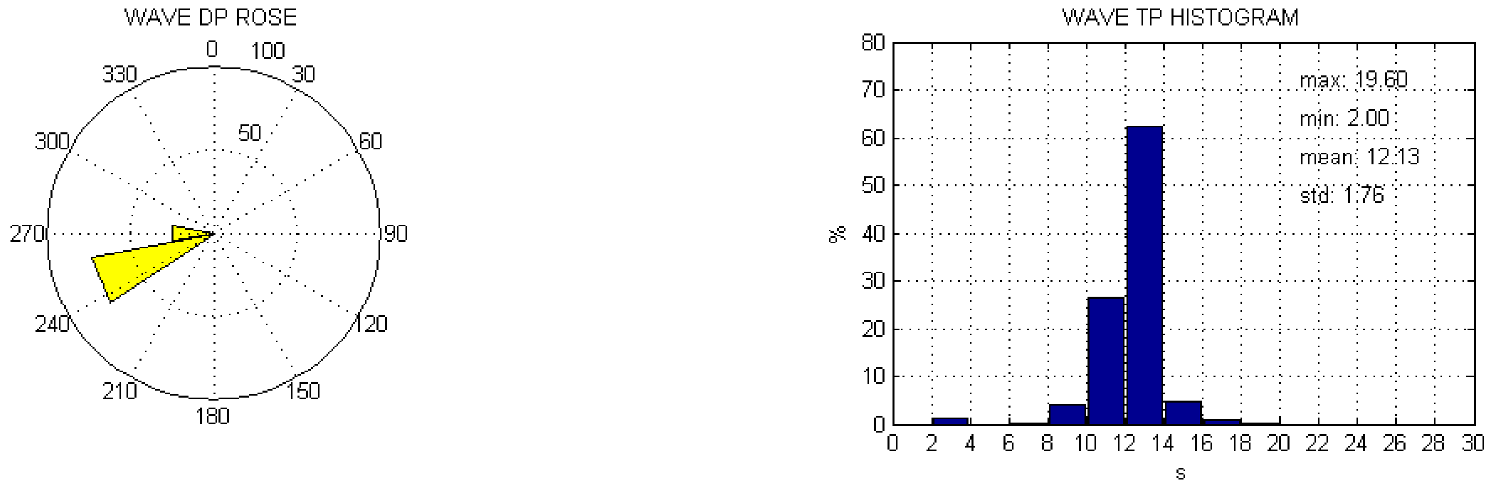


Figure 16: Summary plot of T_p and D_p.

5.1.2.5 Wave spectral plot

Figure 17 and Figure 18 display wave spectral plots for significant waves events. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

5.2 WATER PROPERTIES: RBR-CT LOGGER AND ADCP TEMPERATURE

Figure 19 displays a time series plot, which consists of:

- The first panel is of the observed water temperature from surface and bottom RBR loggers as well as ADCP temperature sensor against time.
- The second panel is of the derived salinity from the two RBR loggers against time.

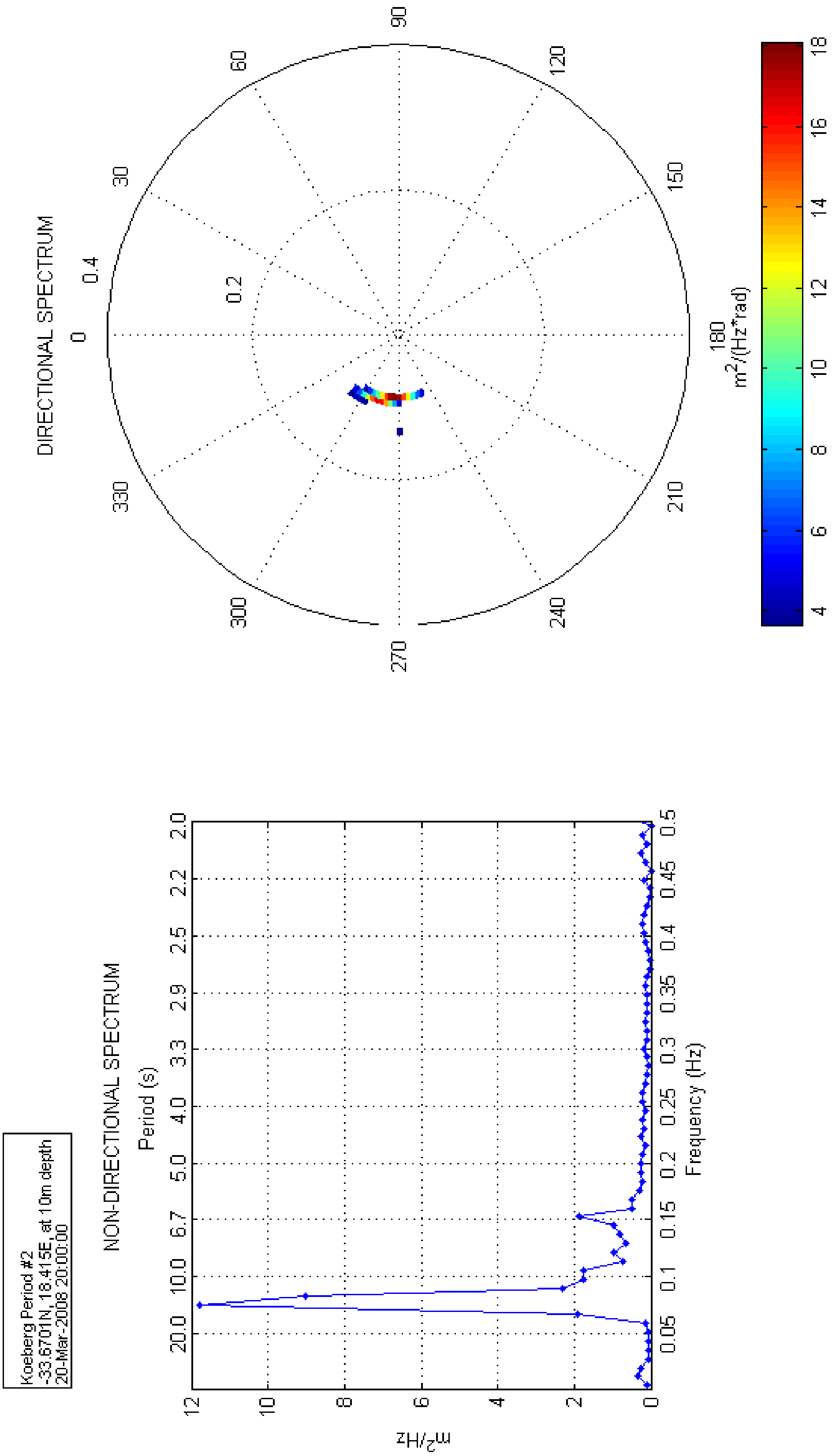


Figure 17: Wave spectra for 20th of March 2008 at 20:00:00.

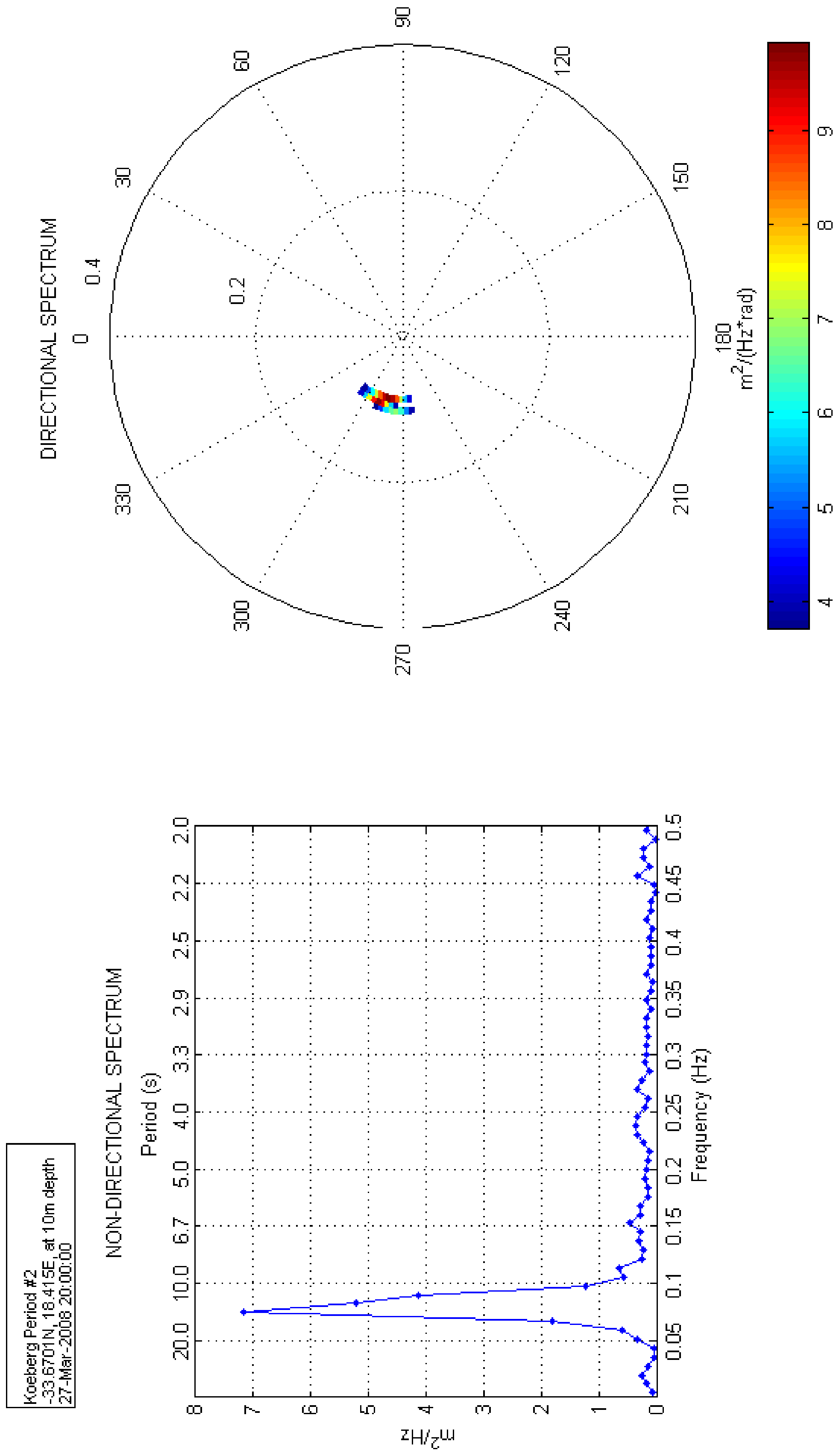


Figure 18: Wave spectra for 27th of March 2008 at 20:00:00.

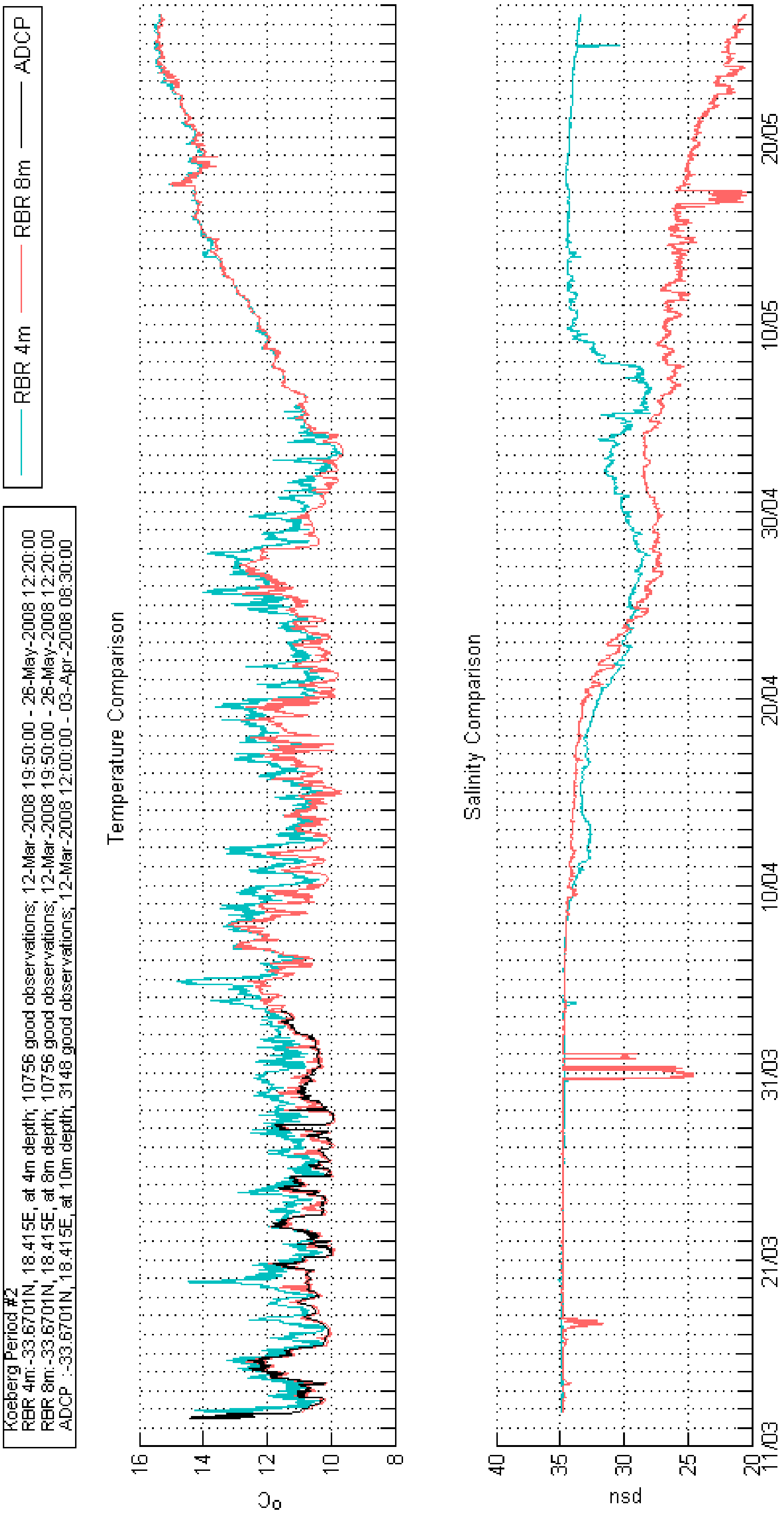


Figure 19: Time series of temperature and salinity from the RBR logger and ADCP.

6. DISCUSSION

The second set of oceanographic data collected ~1 km off the coast of Koeberg (33°40.206' S, 18°24.897' E) for the period between March 12th and May 26th 2008 has been presented in this report. The measurements taken fall within a larger dataset being compiled to assist a preliminary safety survey of multiple sites around the South African coast reports for Eskom.

At the Koeberg site, 1 600 kHz ADCP and 2 RBR-CT loggers have been deployed to measure currents, waves and water temperature and salinity. The ADCP is fixed on a frame at ~10m and the RBR loggers are moored at ~4m and ~8m below the surface. The second recovery of the data was undertaken during May 26th – 29th 2008.The ADCP's pitch and roll sensors showed that the instrument's attitude was within accepted levels. The overall percentage data return for the ADCP and the RBR loggers after careful quality control was found to be good.

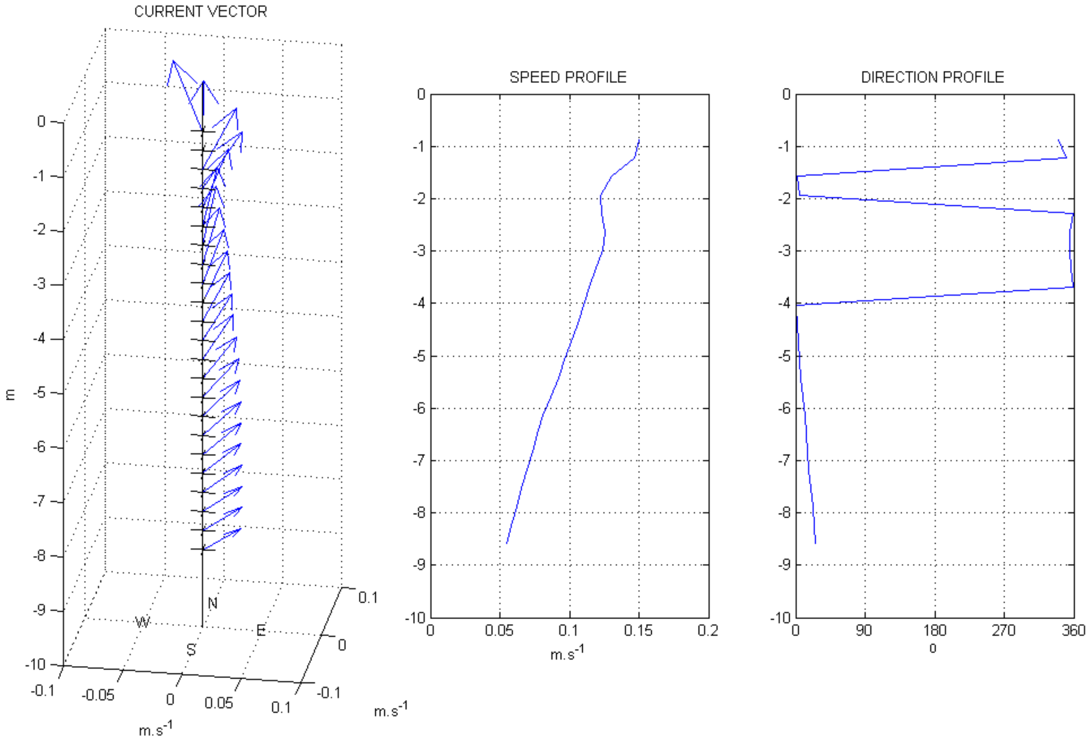


Figure 20: Mean profile plot.

Sediments, water and beach samples were not collected during the service visit and the biofouling plates, which were scheduled for recovery, was lost.

The average surface current speed at site was ~0.15ms^{-1}, decreasing to ~0.0.5ms^{-1} at ~9m depth. The flow throughout the water column was predominantly towards the North. More variability in direction was observed at depth. The mean current profile plot, presented in Figure 20, shows the gradual decrease in the vector mean speed.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.27m, with a wave period of 12.13s and mean direction to W/WSW.

In Figure 19 shows that salinity values started to drift about a month after deployment due to excessive biofouling is responsible (cf Figure 21).

7. INSTRUMENT PARTICULARS FOR SERVICE VISIT ONE

7.1 ADCP RECOVERY AND RE-DEPLOYMENT SHEETS

LWANDLE TECHNOLOGIES (PTY) LTD

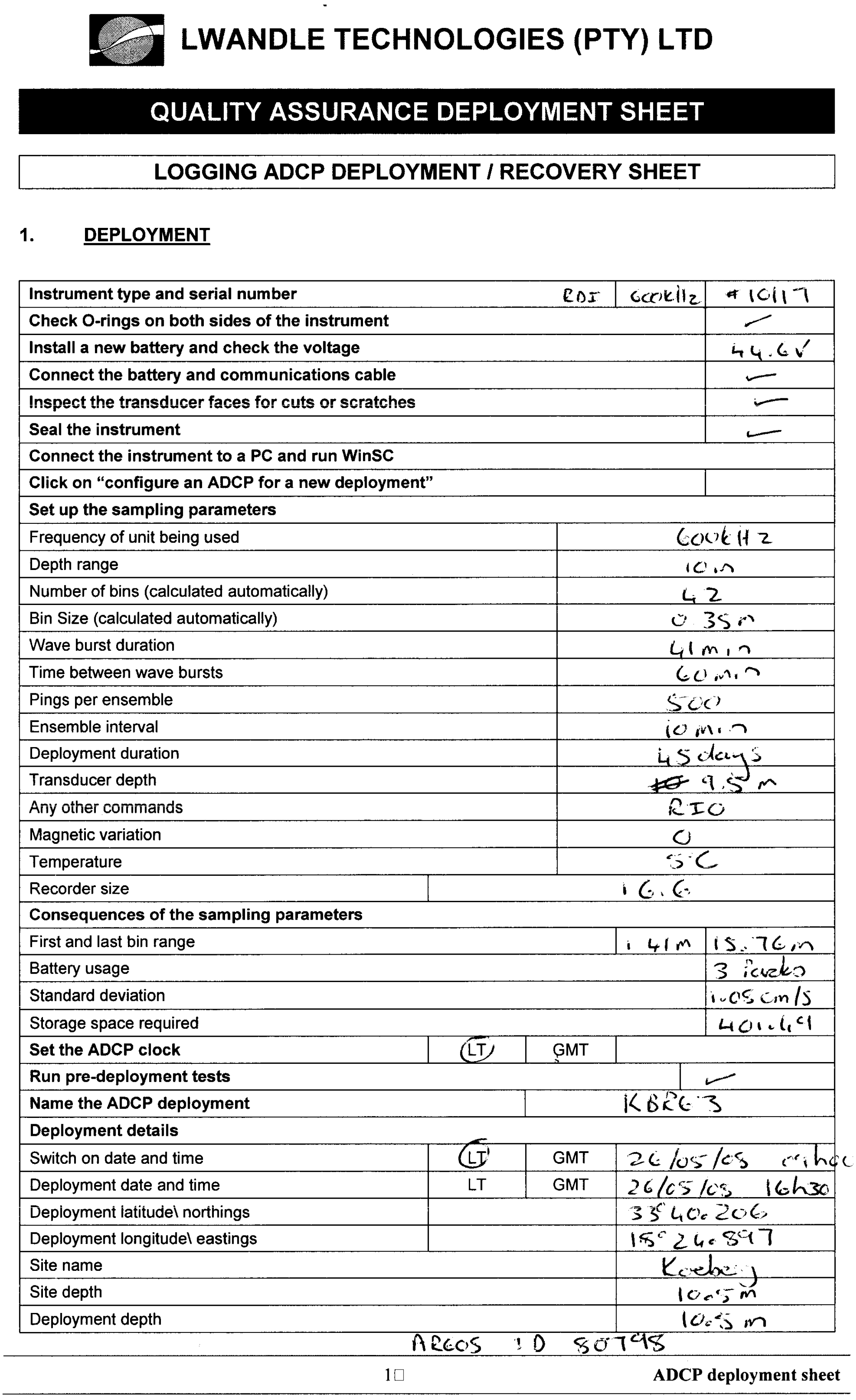
QUALITY ASSURANCE DEPLOYMENT SHEET

LOGGING ADCP DEPLOYMENT / RECOVERY SHEET

Acoustic release (1) serial number and release code		
Acoustic release (2) serial number and release code		
Argos beacon serial number		

2. RECOVERY

Instrument type and serial number			RDI 600	10120
Deployment name			K 6802	
Deployment date and time	[✓ LT]	GMT	12/03/05 10h25	
Deployment latitude\ northings			33°40.206	
Deployment longitude\ eastings			18°24.897	
Recovery information				
Recovery date and time	[✓ LT]	GMT	26/05/05 12h30	
Inspect the transducer faces for cuts or scratches				Fine
Inspect the instrument for signs of flooding				Fine
Switch off and download the instrument using WinSC				
Switch off date and time	[✓ LT]	GMT	INSTrument switched off	
Name of the data directory				
File size				



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

LOGGING ADCP DEPLOYMENT / RECOVERY SHEET

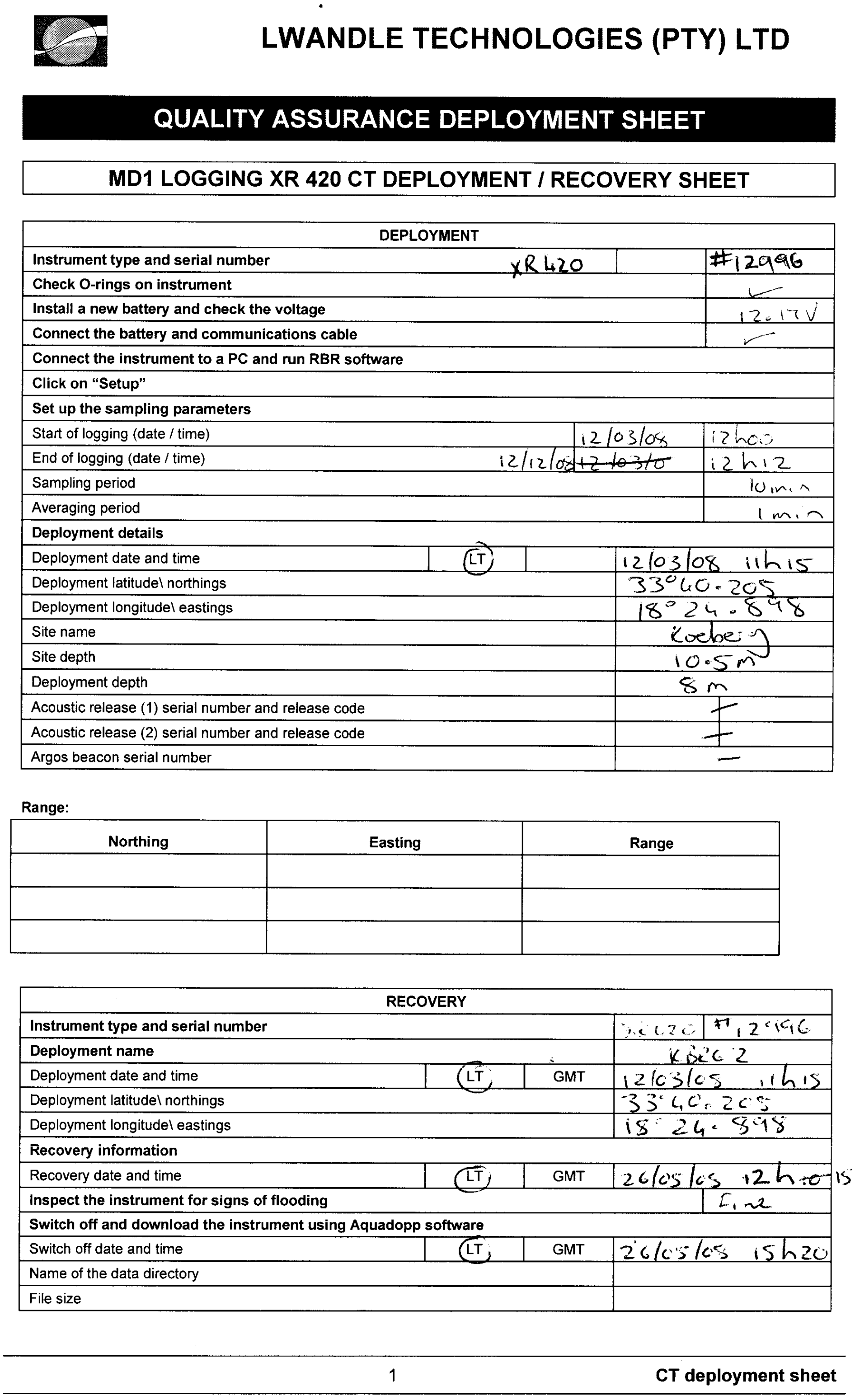
1. DEPLOYMENT

Instrument type and serial number	RDI	600kHz	#10117
Check O-rings on both sides of the instrument			✓
Install a new battery and check the voltage			44.6V
Connect the battery and communications cable			✓
Inspect the transducer faces for cuts or scratches			✓
Seal the instrument			✓
Connect the instrument to a PC and run WinSC			
Click on "configure an ADCP for a new deployment"			
Set up the sampling parameters			
Frequency of unit being used			600kHz
Depth range			10m
Number of bins (calculated automatically)			42
Bin Size (calculated automatically)			0.35m
Wave burst duration			41min
Time between wave bursts			60min
Pings per ensemble			500
Ensemble interval			10min
Deployment duration			45days
Transducer depth			~~10~~ 9.5m
Any other commands			RIO
Magnetic variation			0
Temperature			5°C
Recorder size			16.6
Consequences of the sampling parameters			
First and last bin range		1.41m	15.76m
Battery usage			3 weeks
Standard deviation			1.05cm/s
Storage space required			401.69
Set the ADCP clock	[✓ LT]	GMT	
Run pre-deployment tests			✓
Name the ADCP deployment			KBR63
Deployment details			
Switch on date and time	[✓ LT]	GMT	26/05/08 09h00
Deployment date and time	LT	GMT	26/05/08 16h30
Deployment latitude\ northings			33°40.206
Deployment longitude\ eastings			18°24.897
Site name			Koeberg
Site depth			10.5m
Deployment depth			10.5m

ARGOS ID 80798

1 ADCP deployment sheet

7.2 RBR-CT LOGGERS RECOVERY AND RE-DEPLOYMENT SHEETS



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

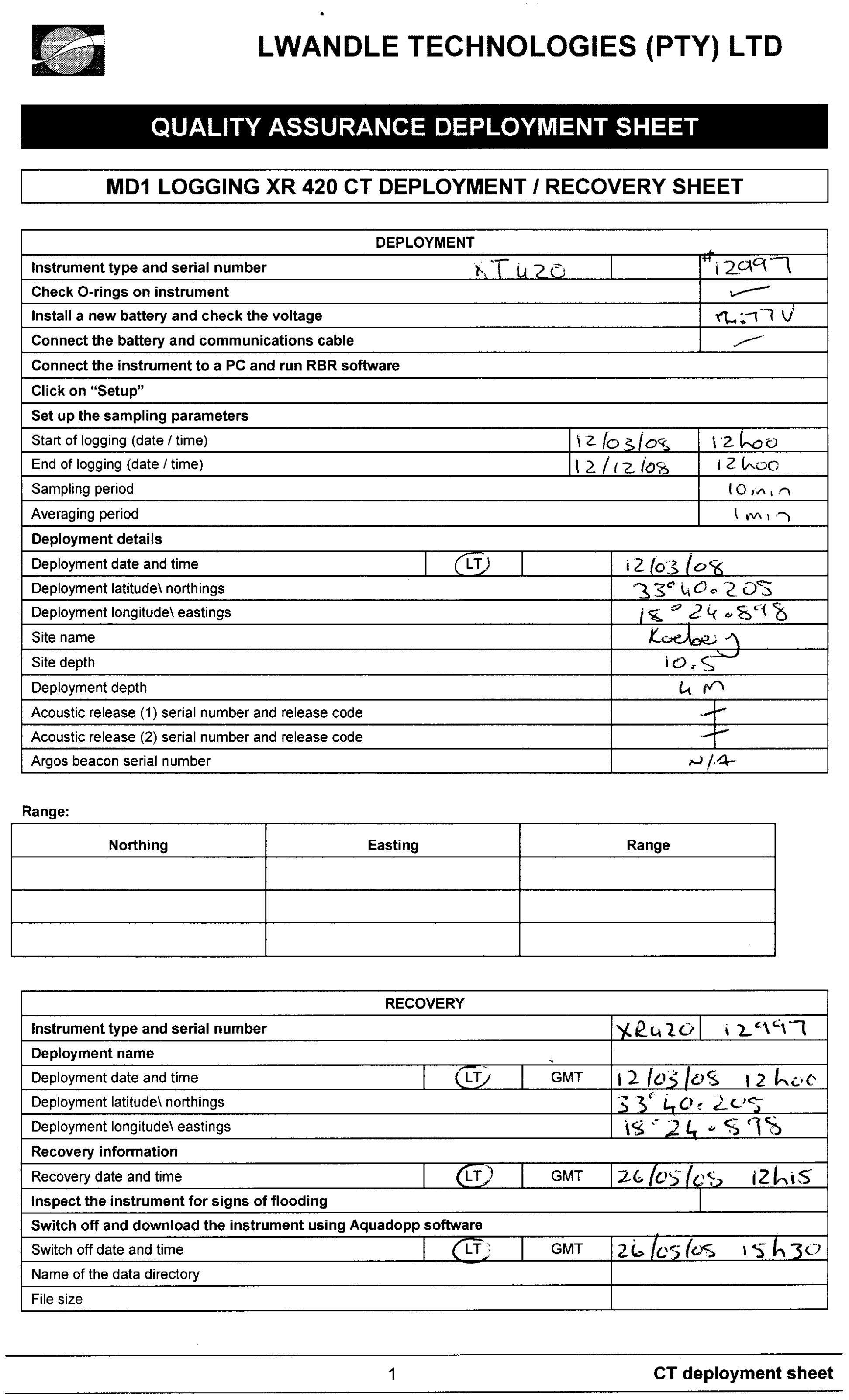
DEPLOYMENT			
Instrument type and serial number	XR420		#12996
Check O-rings on instrument			✓
Install a new battery and check the voltage			12.17V
Connect the battery and communications cable			✓
Connect the instrument to a PC and run RBR software			
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		12/03/08	12h00
End of logging (date / time)	12/12/08	~~12/03/0~~	12h12
Sampling period			10min
Averaging period			1min
Deployment details			
Deployment date and time	[✓ LT]		12/03/08 11h15
Deployment latitude\ northings			33°40.205
Deployment longitude\ eastings			18°24.898
Site name			Koeberg
Site depth			10.5m
Deployment depth			8m
Acoustic release (1) serial number and release code			–
Acoustic release (2) serial number and release code			–
Argos beacon serial number			–

Range:

Northing	Easting	Range

RECOVERY			
Instrument type and serial number		XR420	#12996
Deployment name			KBG 2
Deployment date and time	[✓ LT]	GMT	12/03/08 11h15
Deployment latitude\ northings			33°40.205
Deployment longitude\ eastings			18°24.898
Recovery information			
Recovery date and time	[✓ LT]	GMT	26/05/08 12h~~00~~ 15
Inspect the instrument for signs of flooding			Fine
Switch off and download the instrument using Aquadopp software			
Switch off date and time	[✓ LT]	GMT	26/05/08 15h20
Name of the data directory			
File size			

1 **CT deployment sheet**



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

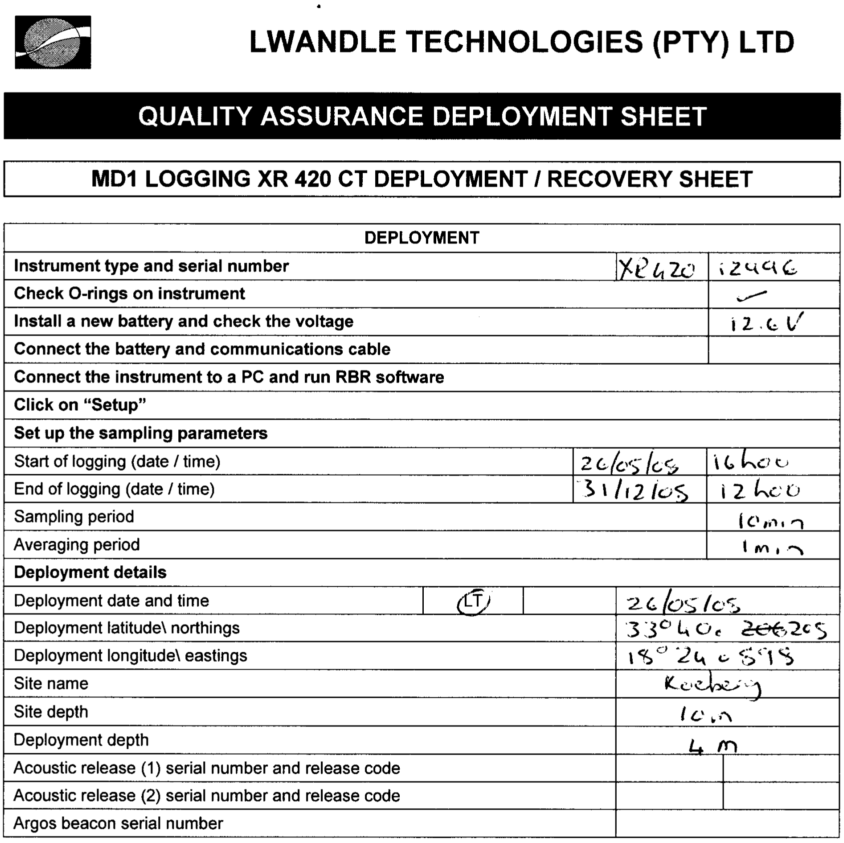
DEPLOYMENT			
Instrument type and serial number	XT420		#12997
Check O-rings on instrument			✓
Install a new battery and check the voltage			12.77V
Connect the battery and communications cable			✓
Connect the instrument to a PC and run RBR software			
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		12/03/08	12h00
End of logging (date / time)		12/12/08	12h00
Sampling period			10min
Averaging period			1min
Deployment details			
Deployment date and time	[✓ LT]		12/03/08
Deployment latitude\ northings			33°40.205
Deployment longitude\ eastings			18°24.898
Site name			Koeberg
Site depth			10.5
Deployment depth			4m
Acoustic release (1) serial number and release code			–
Acoustic release (2) serial number and release code			–
Argos beacon serial number			N/A

Range:

Northing	Easting	Range

RECOVERY			
Instrument type and serial number		XR420	12997
Deployment name			
Deployment date and time	[✓ LT]	GMT	12/03/08 12h00
Deployment latitude\ northings			33°40.205
Deployment longitude\ eastings			18°24.898
Recovery information			
Recovery date and time	[✓ LT]	GMT	26/05/08 12h15
Inspect the instrument for signs of flooding			
Switch off and download the instrument using Aquadopp software			
Switch off date and time	[✓ LT]	GMT	26/05/08 15h30
Name of the data directory			
File size			

1 **CT deployment sheet**

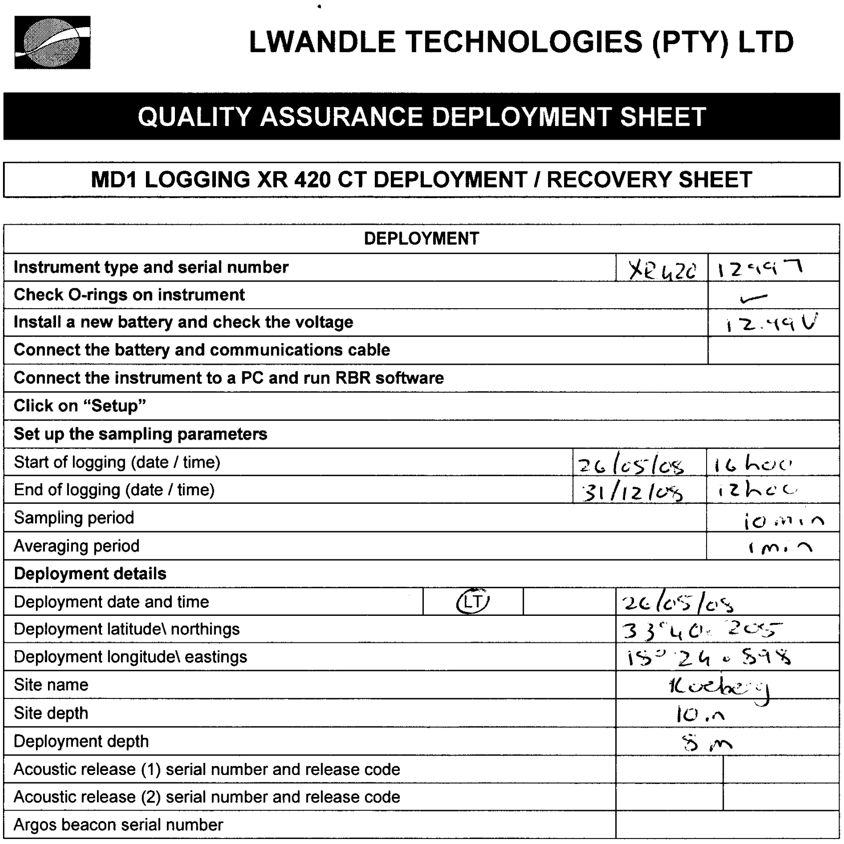


LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

DEPLOYMENT			
Instrument type and serial number		XR420	12496
Check O-rings on instrument			✓
Install a new battery and check the voltage			12.6V
Connect the battery and communications cable			
Connect the instrument to a PC and run RBR software			
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		26/05/08	16h00
End of logging (date / time)		31/12/08	12h00
Sampling period			10min
Averaging period			1min
Deployment details			
Deployment date and time	(LT)		26/05/08
Deployment latitude\ northings			33°40.~~206~~205
Deployment longitude\ eastings			18°24.898
Site name			Koeberg
Site depth			10m
Deployment depth			4 m
Acoustic release (1) serial number and release code			
Acoustic release (2) serial number and release code			
Argos beacon serial number			



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

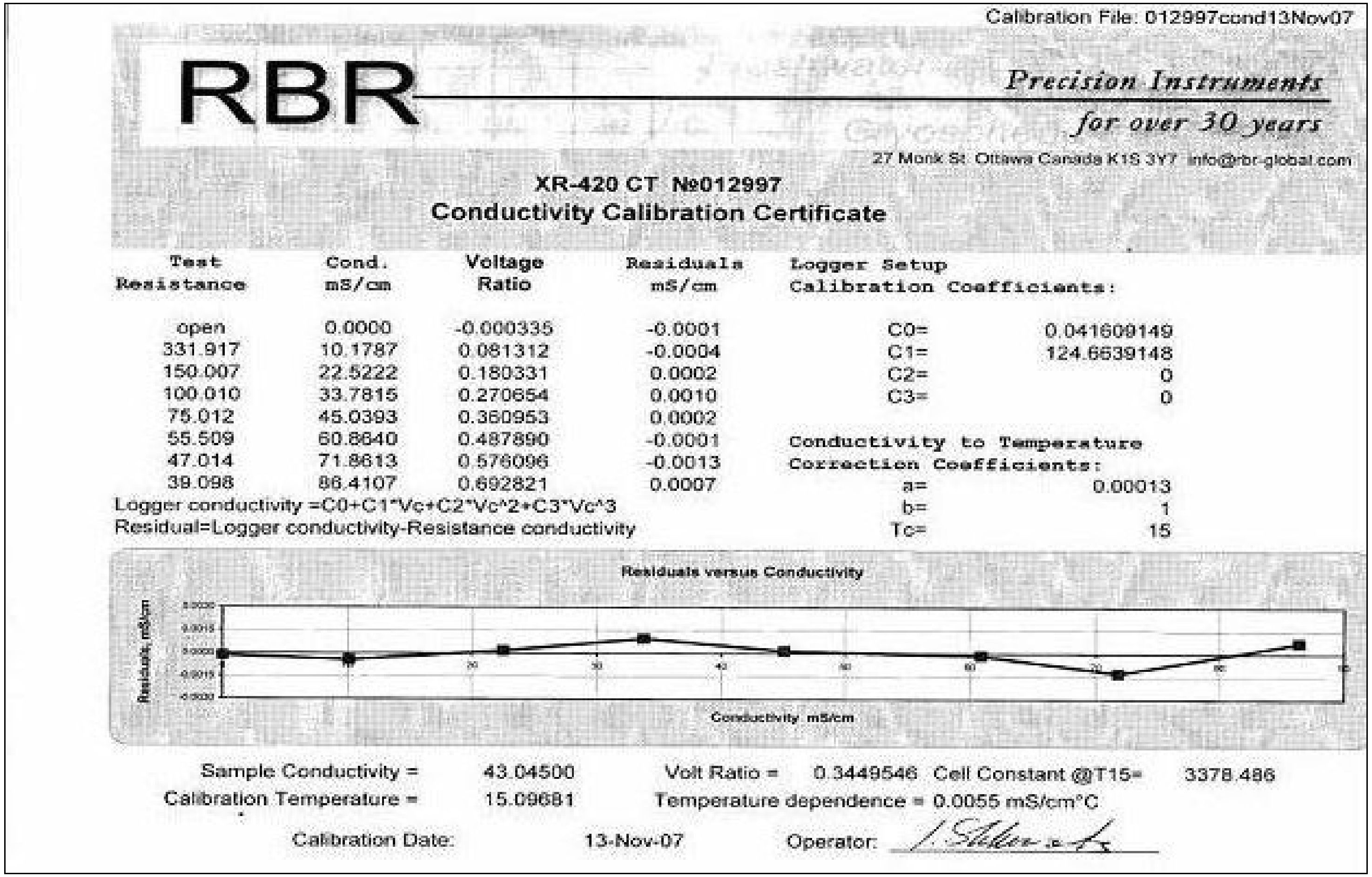
MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

DEPLOYMENT			
Instrument type and serial number		XR420	12497
Check O-rings on instrument			✓
Install a new battery and check the voltage			12.49V
Connect the battery and communications cable			
Connect the instrument to a PC and run RBR software			
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		26/05/08	16h00
End of logging (date / time)		31/12/08	12h00
Sampling period			10min
Averaging period			1min
Deployment details			
Deployment date and time	(LT)		26/05/08
Deployment latitude\ northings			33°40.205
Deployment longitude\ eastings			18°24.898
Site name			Koeberg
Site depth			10m
Deployment depth			8 m
Acoustic release (1) serial number and release code			
Acoustic release (2) serial number and release code			
Argos beacon serial number			

7.3 ADCP CONFIGURATION FILES

```
CR1
CF11101
EA0
EB0
ED100
ES35
RI0
EX11111
EZ1111111
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:01.00
CK
CS
;
;INSTRUMENT        = WORKHORSE SENTINEL
;FREQUENCY         = 614400
;WATER PROFILE     = YES
;BOTTOM TRACK      = NO
;HIGH RES. MODES   = NO
;HIGH RATE PINGING  = NO
;SHALLOW BOTTOM MODE= NO
;WAVE GAUGE        = YES
;LOWERED ADCP      = NO
;BEAM ANGLE        = 20
;TEMPERATURE       = 5.00
;DEPLOYMENT HOURS   = 1080.00
;BATTERY PACKS     = 3
;AUTOMATIC TP      = YES
;MEMORY SIZE [MB]   = 1000
;SAVED SCREEN      = 1
;
;CONSEQUENCES GENERATED BY PLANADCP VERSION 2.04:
;FIRST CELL RANGE   = 1.41 M
;LAST CELL RANGE    = 15.76 M
;MAX RANGE         = 35.28 M
;STANDARD DEVIATION = 1.08 CM/S
;ENSEMBLE SIZE      = 994 BYTES
;STORAGE REQUIRED   = 401.49 MB (420988320 BYTES)
;POWER USAGE        = 1320.77 WH
;BATTERY USAGE      = 2.9
;SAMPLES / WV BURST = 4920
;MIN NONDIR WAVE PER= 1.85 S
;MIN DIR WAVE PERIOD= 2.49 S
;BYTES / WAVE BURST = 383840
```

7.4 RBR-CT CALIBRATION CERTIFICATES



Calibration File: 012997cond13Nov07

RBR *Precision Instruments for over 30 years*

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012997

Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000335	-0.0001
331.917	10.1787	0.081312	-0.0004
150.007	22.5222	0.180331	0.0002
100.010	33.7815	0.270654	0.0010
75.012	45.0393	0.360953	0.0002
55.509	60.8640	0.487890	-0.0001
47.014	71.8613	0.576096	-0.0013
39.098	86.4107	0.692821	0.0007

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.041609149
C1= 124.6539148
C2= 0
C3= 0

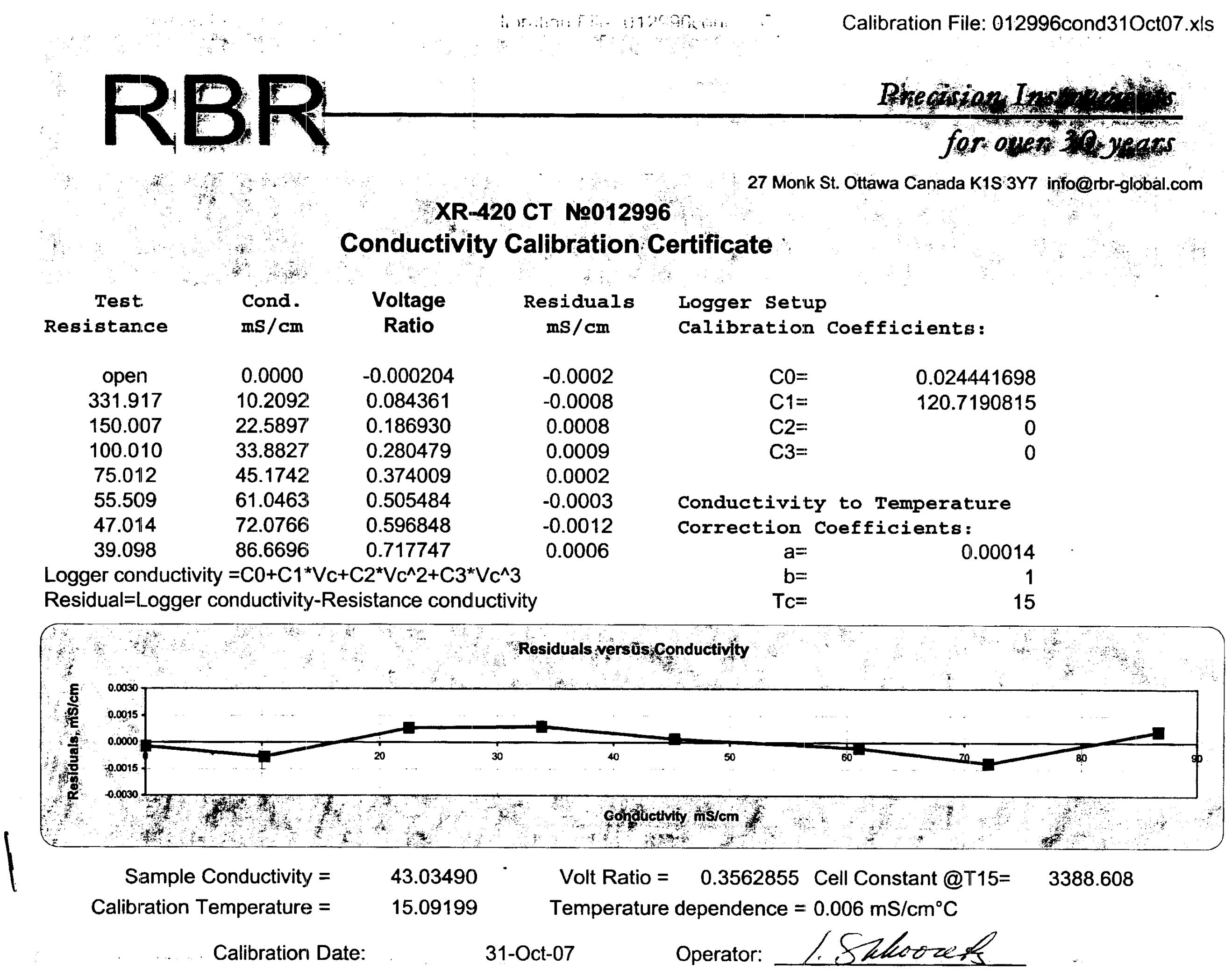
Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 43.04500 Volt Ratio = 0.3449546 Cell Constant @T15= 3378.486
Calibration Temperature = 15.09681 Temperature dependence = 0.0055 mS/cm°C

Calibration Date: 13-Nov-07 Operator:



Calibration File: 012996cond31Oct07.xls

RBR Precision Instruments for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012996
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000204	-0.0002
331.917	10.2092	0.084361	-0.0008
150.007	22.5897	0.186930	0.0008
100.010	33.8827	0.280479	0.0009
75.012	45.1742	0.374009	0.0002
55.509	61.0463	0.505484	-0.0003
47.014	72.0766	0.596848	-0.0012
39.098	86.6696	0.717747	0.0006

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3

Residual=Logger conductivity-Resistance conductivity

`Logger Setup`
`Calibration Coefficients:`

C0= 0.024441698
C1= 120.7190815
C2= 0
C3= 0

`Conductivity to Temperature`
`Correction Coefficients:`

a= 0.00014
b= 1
Tc= 15

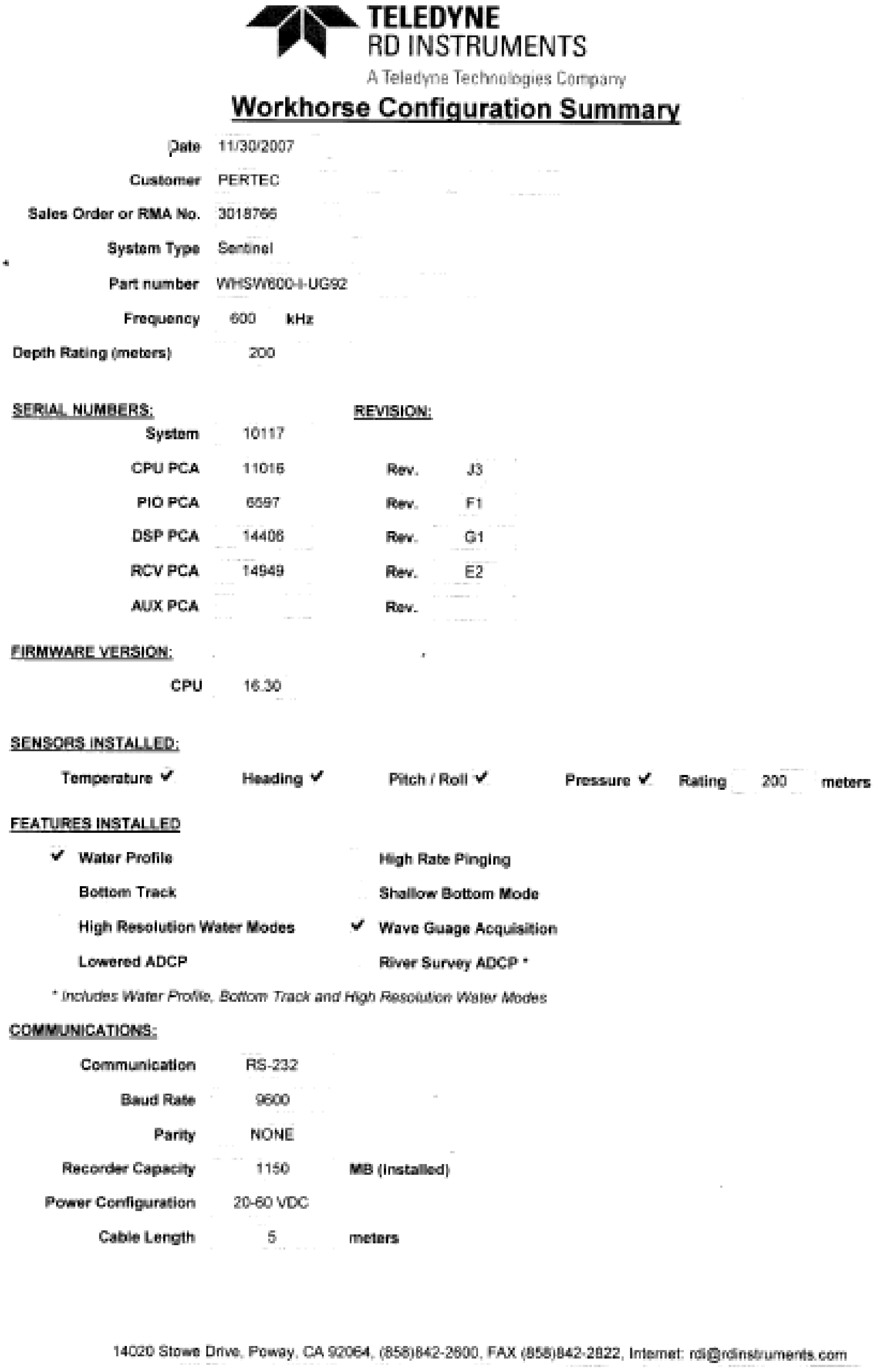
Residuals versus Conductivity

Sample Conductivity = 43.03490 Volt Ratio = 0.3562855 Cell Constant @T15= 3388.608

Calibration Temperature = 15.09199 Temperature dependence = 0.006 mS/cm°C

Calibration Date: 31-Oct-07 Operator: I. Shkoor

7.5 TRDI ADCP CALIBRATION CERTIFICATE



TELEDYNE RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date	11/30/2007
Customer	PERTEC
Sales Order or RMA No.	3018766
System Type	Sentinel
Part number	WHSW600-I-UG92
Frequency	600 kHz
Depth Rating (meters)	200

SERIAL NUMBERS:		**REVISION:**	
System	10117		
CPU PCA	11016	**Rev.**	J3
PIO PCA	6597	**Rev.**	F1
DSP PCA	14406	**Rev.**	G1
RCV PCA	14949	**Rev.**	E2
AUX PCA		**Rev.**	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ **Heading** ✓ **Pitch / Roll** ✓ **Pressure** ✓ **Rating** 200 **meters**

FEATURES INSTALLED

✓ **Water Profile**	**High Rate Pinging**
Bottom Track	**Shallow Bottom Mode**
High Resolution Water Modes	✓ **Wave Guage Acquisition**
Lowered ADCP	**River Survey ADCP ***

* *Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication	RS-232
Baud Rate	9600
Parity	NONE
Recorder Capacity	1150 **MB (Installed)**
Power Configuration	20-60 VDC
Cable Length	5 **meters**

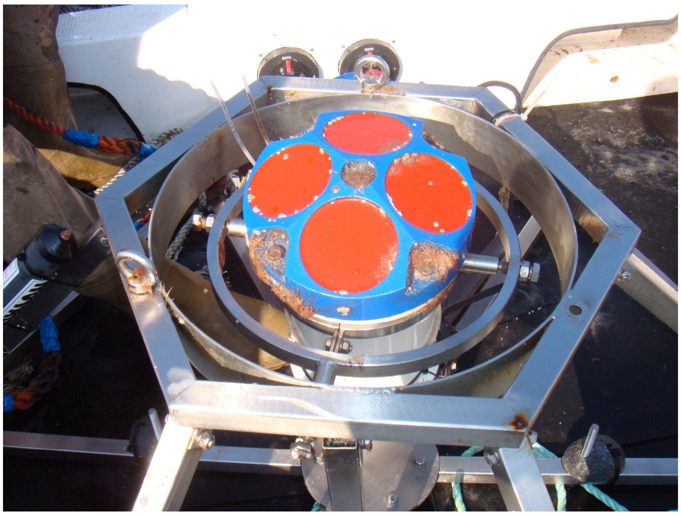
14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com

8. PHOTOS TAKEN

(a)

(b)

(c)



(d)

Figure 21: (a-c) The RBR loggers and ADCP upon recovery. Excessive biofouling on the RBR loggers accounts for the observed drift in the time series (Figure 19). (d) New biofouling plates prior deployment – with smaller plates and plastic backing.

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT THREE

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

09 June 2009

Job No: LT-JOB-50

Directors: C.P. Matthysen, M. Majodina, B.J. Spolander

LWANDLE TECHNOLOGIES (PTY) LTD
Unit 13/15 Constantia Business Park, Princess Vlei Road,
Diep River, 7800, South Africa

Co Reg. No. 2003/015524/07

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 3 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary for 10m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-7.7	99.60	0.8494	0.1237	0.1213	0.0732	214.07
-7.3	99.56	0.8387	0.1258	0.1218	0.0750	214.20
-7.0	99.54	0.8128	0.1270	0.1228	0.0761	214.32
-6.6	99.49	0.7918	0.1279	0.1232	0.0770	215.01
-6.3	99.46	0.8142	0.1289	0.1232	0.0782	215.27
-5.9	99.42	0.8091	0.1301	0.1236	0.0794	216.05
-5.6	99.42	0.8341	0.1317	0.1248	0.0807	217.10
-5.2	99.39	0.8413	0.1328	0.1250	0.0818	218.04
-4.9	99.35	0.8300	0.1342	0.1251	0.0829	218.79
-4.5	99.33	0.8170	0.1358	0.1257	0.0845	219.79
-4.2	99.39	0.8461	0.1379	0.1266	0.0859	221.01
-3.8	99.27	0.8446	0.1398	0.1275	0.0876	221.90
-3.5	99.30	0.8508	0.1419	0.1287	0.0892	223.32
-3.1	99.32	0.7752	0.1441	0.1288	0.0906	224.51
-2.8	99.27	0.8240	0.1461	0.1295	0.0913	225.53
-2.4	99.25	0.8271	0.1471	0.1294	0.0910	226.39
-2.1	99.20	0.8562	0.1475	0.1286	0.0887	226.73
-1.7	98.99	0.8756	0.1472	0.1286	0.0852	225.87
-1.4	98.75	0.9105	0.1489	0.1304	0.0799	223.40
-1.0	93.17	0.9095	0.1555	0.1324	0.0722	216.61

Table 2 – Waves summary for 10m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	69.25	8.68	0.39	2.07	1.00
Tp (s)	69.25	19.60	2.00	12.79	2.20
Dp (^{o})	69.25	317.78	58.78	254.49	15.01

Table 3 – Current flow summary for 30m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-26.5	100.00	0.3048	0.0688	0.0363	0.0159	151.24
-26.0	100.00	0.3070	0.0718	0.0379	0.0159	155.87
-25.5	100.00	0.2898	0.0743	0.0396	0.0157	159.87
-25.0	100.00	0.3048	0.0758	0.0402	0.0151	159.36
-24.5	100.00	0.3204	0.0773	0.0405	0.0146	157.48

-24.0	100.00	0.2992	0.0785	0.0406	0.0139	155.35
-23.5	100.00	0.3061	0.0795	0.0414	0.0130	153.08
-23.0	100.00	0.3193	0.0808	0.0418	0.0125	151.19
-22.5	100.00	0.3163	0.0820	0.0425	0.0113	146.48
-22.0	100.00	0.3310	0.0830	0.0427	0.0101	142.32
-21.5	100.00	0.3149	0.0841	0.0433	0.0090	135.08
-21.0	100.00	0.3126	0.0853	0.0436	0.0082	124.2
-20.5	100.00	0.3087	0.0858	0.0439	0.0072	113.43
-20.0	100.00	0.3030	0.0867	0.0440	0.0072	106.46
-19.5	100.00	0.3031	0.0870	0.0441	0.0070	92.60
-19.0	100.00	0.3042	0.0878	0.0444	0.0067	83.78
-18.5	100.00	0.3051	0.0883	0.0446	0.0071	77.04
-18.0	100.00	0.2996	0.0884	0.0450	0.0071	70.56
-17.5	100.00	0.3007	0.0891	0.0455	0.0068	65.95
-17.0	100.00	0.2974	0.0895	0.0457	0.0074	61.83
-16.5	99.98	0.2956	0.0897	0.0458	0.0077	61.58
-16.0	99.98	0.3108	0.0903	0.0461	0.0077	60.32
-15.5	99.95	0.2971	0.0907	0.0462	0.0079	57.62
-15.0	99.98	0.2914	0.0911	0.0468	0.0078	55.60
-14.5	99.98	0.2943	0.0917	0.0469	0.0078	56.39
-14.0	99.98	0.2974	0.0922	0.0469	0.0077	55.69
-13.5	99.98	0.2938	0.0925	0.0470	0.0073	52.94
-13.0	99.98	0.3125	0.0924	0.0475	0.0072	55.60
-12.5	99.98	0.3153	0.0928	0.0475	0.0071	55.00
-12.0	99.98	0.3230	0.0935	0.0477	0.0066	56.09
-11.5	99.98	0.3408	0.0937	0.0483	0.0064	55.31
-11.0	99.98	0.3461	0.0944	0.0485	0.0058	49.93
-10.5	99.98	0.3503	0.0950	0.0491	0.0053	51.13
-10.0	99.98	0.3613	0.0957	0.0496	0.0047	50.74
-9.5	99.98	0.3522	0.0962	0.0502	0.0043	52.95
-9.0	99.98	0.3620	0.0971	0.0506	0.0036	56.40
-8.5	99.98	0.3609	0.0982	0.0512	0.0030	53.08
-8.0	99.98	0.3949	0.0987	0.0522	0.0023	66.14
-7.5	99.98	0.3855	0.0995	0.0532	0.0016	74.00
-7.0	99.98	0.3825	0.1008	0.0541	0.0013	111.87
-6.5	99.98	0.3981	0.1022	0.0550	0.0017	153.86
-6.0	99.98	0.3996	0.1036	0.0564	0.0020	167.61
-5.5	100.00	0.4020	0.1050	0.0569	0.0027	180.66
-5.0	99.93	0.4031	0.1064	0.0583	0.0036	173.67
-4.5	99.93	0.4121	0.1082	0.0595	0.0042	158.50
-4.0	99.91	0.4178	0.1112	0.0602	0.0090	123.21
-3.5	99.93	0.4188	0.1189	0.0640	0.0252	108.26
-3.0	99.98	0.3995	0.1316	0.0706	0.0478	102.55
-2.5	99.75	0.4095	0.1469	0.0758	0.0626	103.84
-2.0	73.95	0.4807	0.1604	0.0790	0.0627	111.79

Table 4 – Waves summary for 30m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	97.11	7.27	0.50	2.27	1.07
Tp (s)	97.11	19.50	4.50	12.26	2.25
Dp (^{o})	97.11	312.78	215.78	258.36	14.55

Table 5 – Water temperature and salinity summary for surface 4m RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100.00	14.93	17.39	12.71
Conductivity	100.00	42.63	45.33	40.32
Salinity (psu)	95.99	34.84	35.20	34.00

Table 6 – Water temperature and salinity summary for bottom 8m RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100.00	14.84	16.77	12.51
Conductivity	100.00	42.31	44.82	20.58
Salinity (psu)	96.25	34.70	35.19	33.00

Table 7 – Water temperature summary for Thermister String

(^{o}C)	Data Return (%)	Mean	Max	Min
Temperature at 30m depth	88.88	13.67	14.20	12.64
Temperature at 29m depth	87.21	13.71	14.20	12.78
Temperature at 19m depth	84.38	13.83	15.44	13.29
Temperature at 9m depth	100.00	14.07	15.86	13.34

1.1 DATA RETURN FOR KOEBERG SITE.

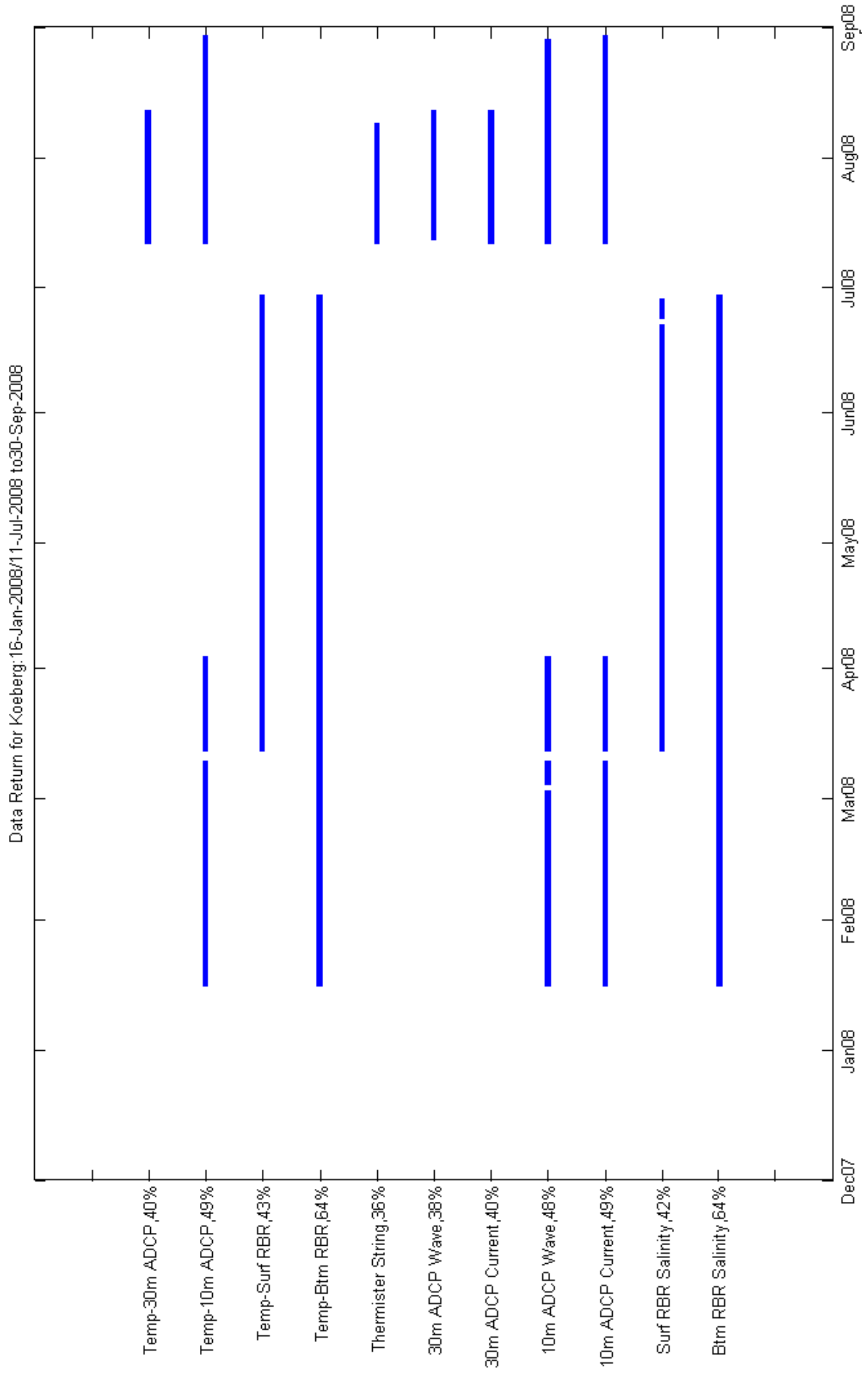


Figure 1: An indication of the data return (%) at the Koeberg site since the beginning of the project (Jan 16th 2008; July 11th 2008 for 30m ADCP and Thermister String). A break down of the temperature (Temp) return from all available instruments is given in the top 5 bars.

2. INTRODUCTION

2.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period May 25th 2008 - September 21st 2008 (Period 3). Four service visits were undertaken at irregular intervals due to unfavourable weather conditions over the winter months: SV3a – June 29th, SV3b – July 11th, SV3c – September 21st, and SV3d October 18-19th. Water samples were collected during SV3a, b and d. Biofouling plates were recovered during SV3d.

2.2 EQUIPMENT LIST

Lwandle provided the equipment as listed in Table 8 for the Koeberg site.

Table 8 – List of equipment provided.

Item	Operational (on site)	Spare (for whole project)
TRDI 600kHz ADCP	2	1
RBR XR420 CT logger	2	1
RBR Thermister String	1	0

2.3 MEASUREMENT LOCATION

The deployment locations of the moorings are recorded in Table 9.

Table 9 – Initial deployment locations.

Instrument	Latitude (°S)	Longitude (°E)
10m ADCP and RBR CT logger string.	33.6701	18.4150
30m ADCP and Thermister String	33.6757	18.3898

Table 10 – Locations where water samples were taken during service visit 3a

Station		Latitude (^oS)	Longitude (^oE)
S1	10m Site 2m	33.6701	18.4150
S2	10m Site 4m	33.6701	18.4150
S3	10m Site 6m	33.6701	18.4150
S4	10m Site 8m	33.6701	18.4150
S5		33.6751	18.4242
S6		33.6722	18.4228
S7		33.6704	18.4208
S8		33.6679	18.4193
S9		33.6651	18.4173
S10		33.6608	18.4141
S11		33.6563	18.4119

Table 11 – Locations where water samples were taken during service visit 3b

Station		Latitude (^oS)	Longitude (^oE)
S1	30m Site 4m	33.6757	18.3898
S2	30m Site 12m	33.6757	18.3898
S3	30m Site 20m	33.6757	18.3898
S4	30m Site 28m	33.6757	18.3898
S5	10m Site 4m	33.6701	18.4150
S6	10m Site 8m	33.6701	18.4150
S7		33.6751	18.4242
S8		33.6722	18.4228
S9		33.6704	18.4208
S10		33.6679	18.4193
S11		33.6651	18.4173

Table 12 – Locations where water samples were taken during service visit 3d

Station		Latitude (^oS)	Longitude (^oE)
S1	30m Site 4m	33.6757	18.3890
S2	30m Site 12m	33.6757	18.3890
S3	30m Site 20m	33.6757	18.3890
S4	30m Site 28m	33.6757	18.3890
S5	10m Site 4m	33.6701	18.4150
S6	10m Site 8m	33.6701	18.4150
S7		33.6688	18.4153
S9		33.6691	18.4159
S10		33.6693	18.4161
S11		33.6695	18.4164
S12		33.6697	18.4167

3. OPERATIONS

3.1 SUMMARY OF EVENTS.

Service visit 4 was undertaken in four parts as outlined below.

SV3a – June 29th 2008.
The 10m ADCP (s/n 10117) was recovered by no data was recorded on the unit. The CT-Loggers were recovered (s/n 12996 and 12997) and water samples taken. The 10m ADCP was withdrawn and bench tests were carried out.

SV3b – July 11th 2008.
Deployment of the 10m ADCP (s/n 10105), 30m ADCP (s/n 10841) and Thermister string (s/n 15135) were undertaken and water samples taken.

SV3c – September 21st 2008.
The 30m ADCP and Thermister string were recovered. There was a fault on Thermister string. However, some data has been recovered successfully. The 10m ADCP was completely sanded over and recovery was not possible.

SV3d – October 18 – 19th 2008.
On the 18th, the 30m ADCP (s/n 10119) was redeployed with a RBR-CT Logger attached to the frame (s/n 12997). The 10m ADCP was recovered. Water samples at the 30m site were collected and biofouling plates recovered.

On the 19th, the 10m ADCP (s/n 11424) was redeployed with a RBR-CT Logger attached to the frame (s/n 12995). Water samples at the 10m site were collected.

3.2 INSTRUMENT CONFIGURATIONS

The deployed instrumentation configurations are given in this section and completed deployment / recovery sheets are given as an appendix (Section 7, page 56) to this report.

3.2.1 600kHz ADCP

Table 13 – Instrument configuration for the 10m ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	10117
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.35 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

The s/n 10117 unit was replaced during SV3b with unit s/n 10105, which was replaced again during SV3d with unit s/n 11424.

Table 14 – Instrument configuration for the 30m ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	10119
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.5 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

3.2.2 RBR XR420 CT LOGGER

Table 15 – Instrument configuration for T&C Mooring Line.

Parameter	Configuration
XR 420 Temperature and Conductivity	s/n 12996 (4m) and s/n 12997 (8m)
Sampling and Averaging	Sample at 1Hz for 1 minute every 10 minutes

During SV3d, two loggers were attached to the frames – s/n 12995 and 12997 were placed at the 10m and 30m sites respectively.

3.2.3 Thermister String

Table 16 – Instrument configuration for Thermister String.

Parameter	Configuration
XR 420 Temperature and Conductivity	s/n 15135 with nodes at 30m, 29m, 19m and 9m below the surface.
Sampling and Averaging	Sample at 1Hz for 1 minute every 10 minutes

3.2.4 Biofouling Mooring

Table 17 – Instrument configuration for Biofouling Mooring Line.

Parameter	Configuration
Biofouling Plates	3 plates (20cmx20cm) at 3m and 3 plates (20cmx20cm) at 8m
Edgetech Acoustic Release	s/n 32385 release code 642102

3.3 RECOVER AND REDEPLOYMENT METHODOLOGY

3.3.1 T&C mooring and Thermister string

The T&C mooring line was deployed by lowering the array down via a rope through the anchor weights. The mooring line is recovered using divers to undo a single shackle that connects the mooring line to the anchor weights. Divers reattach the line onto the weights, after the instruments have been serviced.

The Thermister string is attached to the 30m ADCP frame. The string comprises of four nodes at 30m, 29m, 19m, and 9m below the surface.

3.3.2 ADCP mooring

The ADCP Frame is lowered to the bottom and moved into position by divers, who also attach chain sections that act as anchors. To retrieve the frame divers have to locate the mooring, take off the anchor chains and surface the frame using air lift bags that they attach.

Figure 2 – ADCP frame with 600KHz instrument.

3.3.3 Biofouling mooring

The biofouling mooring line was deployed by lowering the array down via a rope through the anchor weights. Divers would locate the mooring line and retrieve a surface and bottom plate from the line at the required sampling periods.

4. DATA QUALITY CONTROL

4.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

4.1.1 Current processing

- The record was truncated to exclude times pre and post deployment.
- Directions were adjusted from magnetic to true north using a magnetic variation of 23° 13' W (both ADCP sites).
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP's pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of $0.2ms^{-1}$ was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined.
- During SV3c, it was found that the10m ADCP was sanded over. Recovery was undertaken a few weeks later. Current data beyond August 29th has been discarded (The temperature sensor on the ADCP continued to record sensible data).
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

4.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 23° 13' W (both ADCP sites).
- Wave data beyond August 29th has been discarded for the 10m ADCP.
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

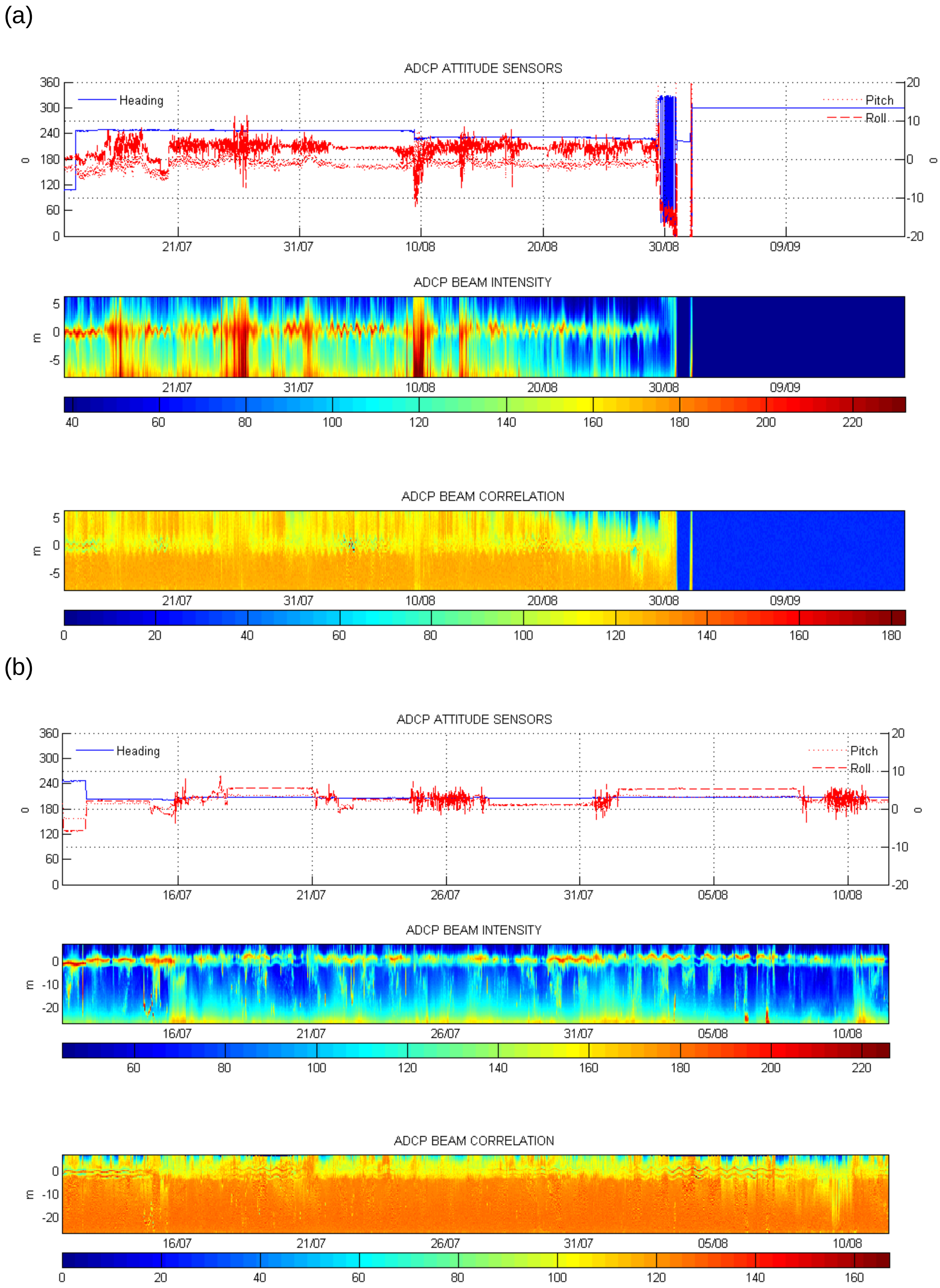


Figure 3: Quality control data from the (a) 10m and (b) 30m ADCPs. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

4.2 RBR-CT LOGGER AND THERMISTER STRING

The conductivity (from the CT-logger) and temperature data were exported directly from the RBR software into Matlab for further processing.

- The record was truncated to exclude times pre and post deployment.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.
- Salinity less than 34 and 33 psu were discarded for the 4m and 8m unit respectively.

4.3 BIOFOULING.

The following standard procedure is normally followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates are measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 CaC03 chips are added.
- Sample bottles are stored upright in the dark.

Recovery of the biofouling plates was undertaken during visit 3d. A separate report has been issued.

4.4 WATER SAMPLE.

Water sample were collected during SV3a, b and d and sent to the Council for Scientific and Industrial Research (CSIR) for analysis.

5. DATA PRESENTATION

All data presented have been subject to the quality control procedures detailed in the previous section. Bad data have been excluded from all plots and calculations.

All plots in this section include a stamp that details the location, depth, time period and number of observations that the plot is based upon. Wherever possible, scaling of parameters has been kept constant throughout this section to facilitate comparison between plots and stations.

5.1 10M ADCP

5.1.1 Current Data

5.1.1.1 Time series plot

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

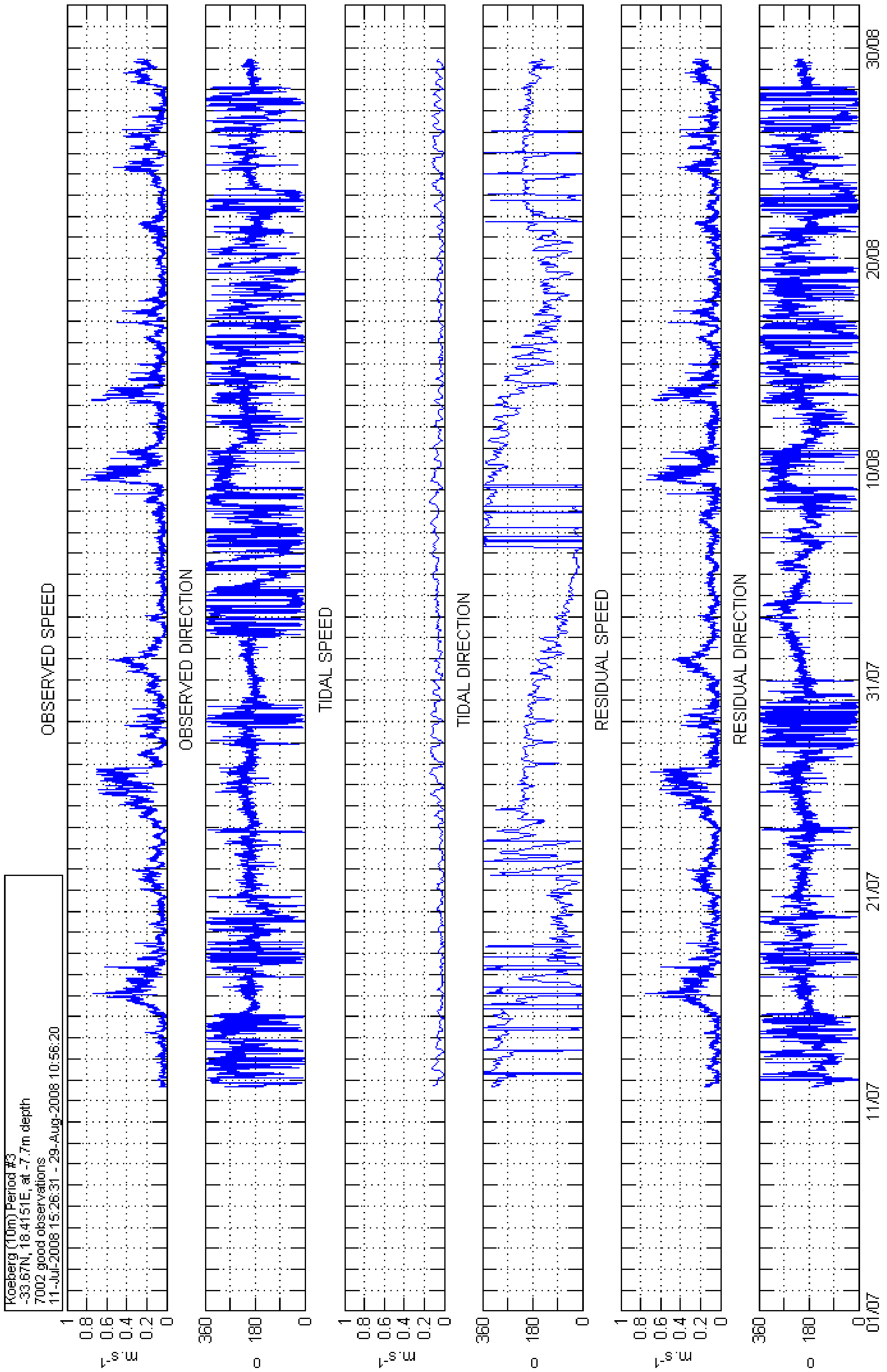


Figure 4: Time series plot of the 10m ADCP's current data at 7.7m.

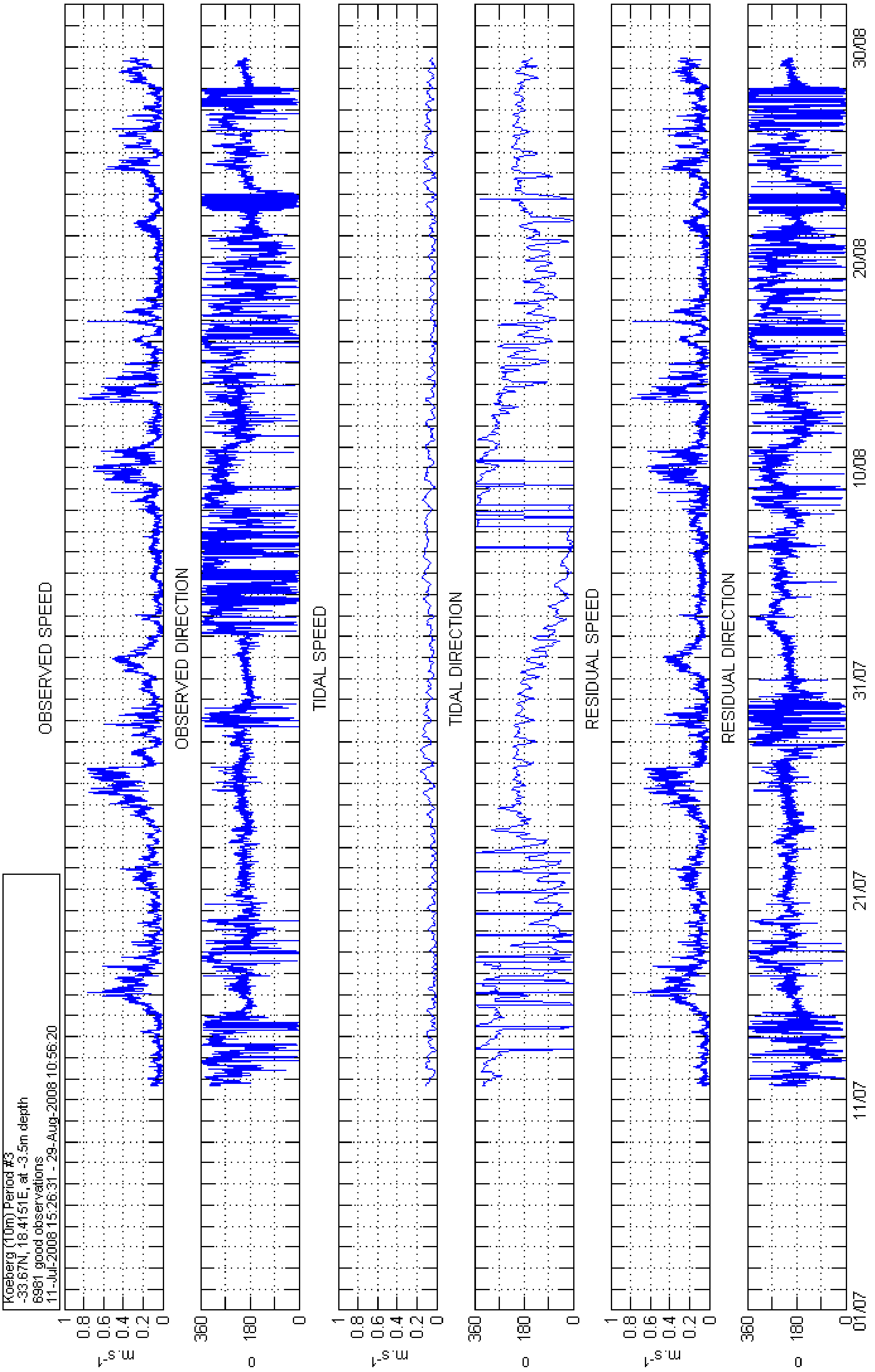


Figure 5: Time series plot of the 10m ADCP's current data at 3.5m.

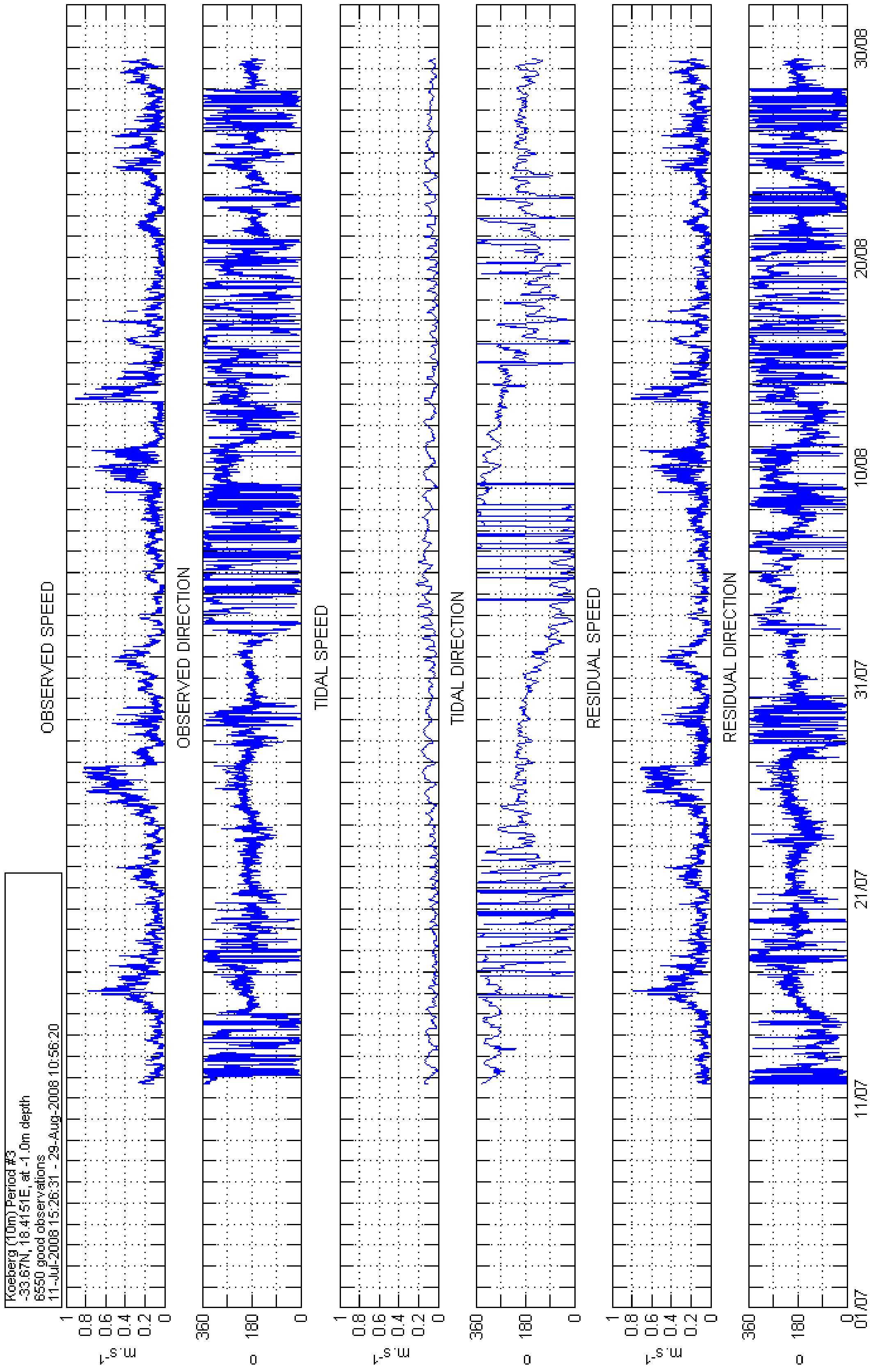


Figure 6: Time series plot of the 10m ADCP's current data at 1.0m.

5.1.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg (10m) Period #3
-33.67N, 18.4151E, at -7.7m depth
7002 good observations
11-Jul-2008 15:26:31 - 29-Aug-2008 10:56:20

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	2.71	3.23	2.68	2.37	2.76	2.73	3.26	4.17	6.91	6.93	5.21	3.51	2.87	2.97	3.03	3.43	58.77
0.1-0.2	0.71	0.43	0.10	0.26	0.16	0.37	0.33	1.37	6.13	6.24	2.24	1.01	0.79	0.71	0.84	1.16	22.85
0.2-0.3	0.14		0.01	0.03	0.01	0.03	0.06	0.36	2.47	3.38	1.39	0.46	0.34	0.41	0.27	0.24	9.61
0.3-0.4	0.01		0.01				0.01	0.09	0.97	1.46	0.80	0.36	0.29	0.24	0.06	0.04	4.34
0.4-0.5	0.03	0.01						0.01	0.17	0.80	0.40	0.23	0.16	0.16	0.10		2.07
0.5-0.6								0.01	0.11	0.43	0.34	0.19	0.07	0.24	0.06	0.01	1.47
0.6-0.7									0.03	0.16	0.17	0.03	0.04	0.13	0.10		0.66
0.7-0.8									0.01	0.01	0.01		0.01	0.10	0.06		0.21
0.8-0.9														0.01			0.01
0.9-1																	0.00
Σ	3.61	3.67	2.81	2.66	2.93	3.13	3.66	6.01	16.81	19.41	10.57	5.78	4.57	4.98	4.51	4.88	100.00

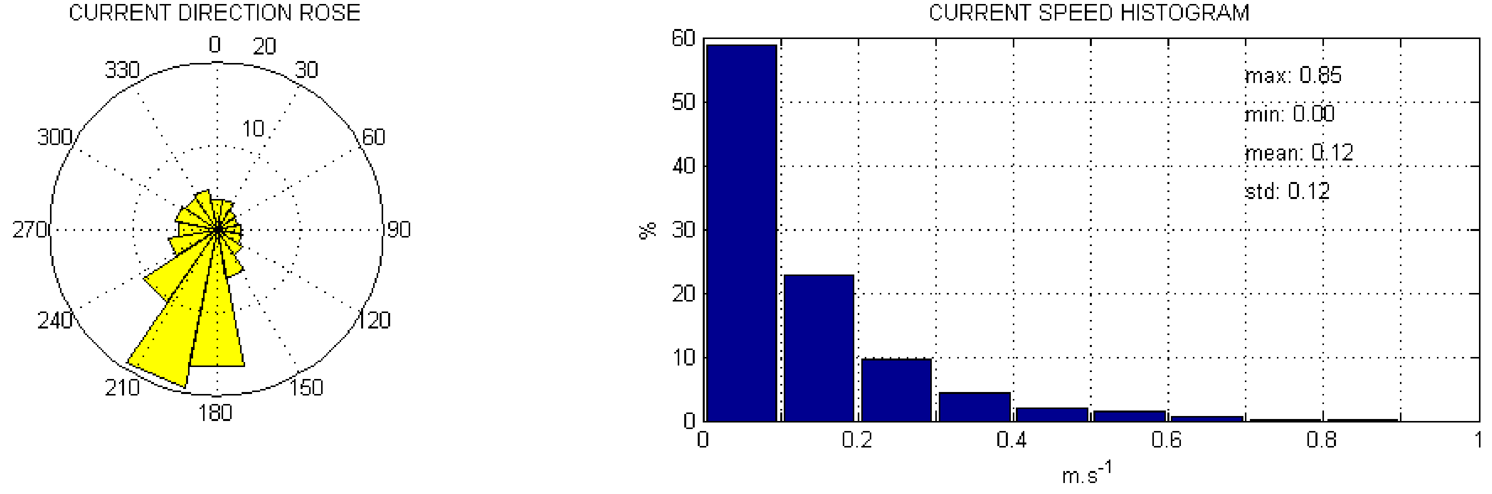
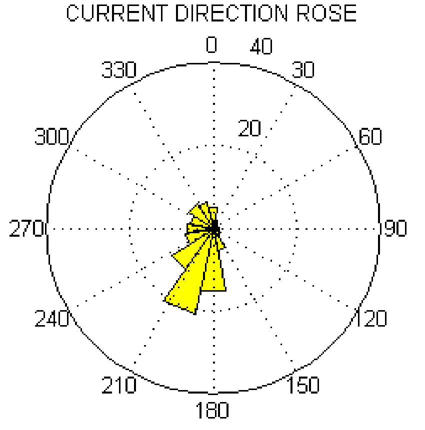


Figure 7: Summary plot of the 10m ADCP's current data at 7.7m.

Koeberg (10m) Period #3
-33.67N, 18.4151E, at -3.5m depth
6981 good observations
11-Jul-2008 15:26:31 - 29-Aug-2008 10:56:20

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	3.67	1.69	1.30	0.97	1.22	1.36	1.92	3.81	5.74	5.77	4.90	3.51	3.07	2.97	4.27	4.07	50.24
0.1-0.2	0.90	0.19	0.11	0.14	0.07	0.17	0.20	1.23	6.12	7.06	3.09	1.42	1.40	1.09	1.58	1.70	26.49
0.2-0.3	0.46	0.01				0.01	0.03	0.27	2.29	4.31	1.68	0.66	0.63	0.52	0.60	0.57	12.05
0.3-0.4	0.01	0.01						0.06	0.80	2.18	0.95	0.44	0.52	0.33	0.26	0.06	5.62
0.4-0.5									0.23	1.05	0.64	0.34	0.30	0.19	0.14	0.01	2.91
0.5-0.6	0.01								0.11	0.56	0.36	0.21	0.17	0.19	0.07	0.01	1.70
0.6-0.7									0.03	0.27	0.19	0.06	0.06	0.09			0.69
0.7-0.8									0.03	0.11	0.07	0.01	0.03	0.03	0.01		0.30
0.8-0.9											0.01						0.01
0.9-1																	0.00
Σ	5.06	1.91	1.42	1.12	1.29	1.55	2.15	5.37	15.36	21.31	11.89	6.66	6.17	5.39	6.93	6.43	100.00



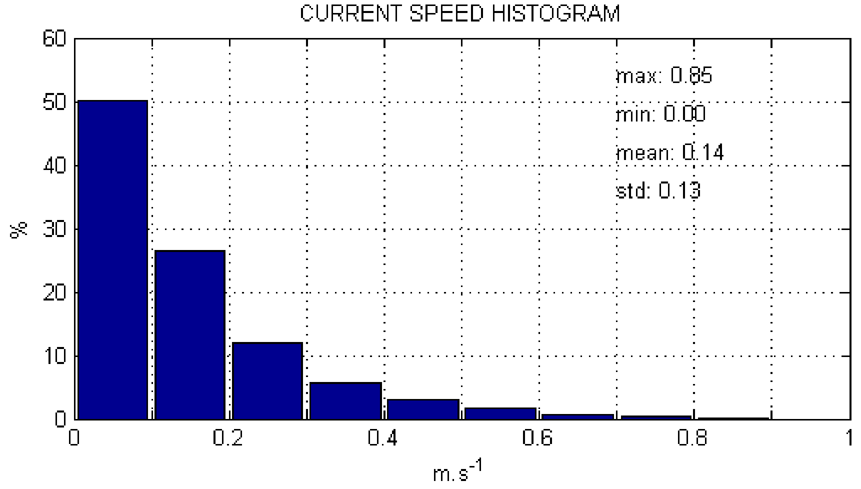
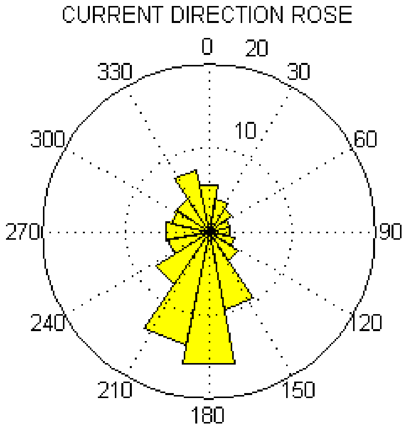


Figure 8: Summary plot of the 10m ADCP's current data at 3.5m.

Koeberg (10m) Period #3
-33.67N, 18.4151E, at -1.0m depth
6550 good observations
11-Jul-2008 15:26:31 - 29-Aug-2008 10:56:20

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	2.76	2.73	2.20	1.94	1.69	2.06	2.49	4.17	4.49	3.47	2.84	1.82	2.27	2.08	2.47	3.11	42.60
0.1-0.2	2.38	1.21	1.08	0.61	0.70	1.10	1.71	4.23	6.70	4.03	1.59	1.19	1.07	1.05	1.19	3.07	32.92
0.2-0.3	0.37	0.06	0.02	0.05	0.09	0.02	0.09	1.16	3.66	2.69	0.96	0.73	0.58	0.50	0.53	0.92	12.43
0.3-0.4	0.23							0.08	0.96	1.60	0.82	0.47	0.44	0.41	0.24	0.50	5.77
0.4-0.5								0.02	0.23	1.05	0.58	0.49	0.27	0.23	0.17		3.04
0.5-0.6									0.12	0.58	0.34	0.20	0.34	0.17			1.74
0.6-0.7									0.03	0.32	0.23	0.08	0.14	0.08			0.87
0.7-0.8									0.03	0.17	0.21	0.03	0.05	0.03			0.52
0.8-0.9										0.03	0.03		0.02	0.02			0.09
0.9-1														0.03			0.03
Σ	5.74	4.00	3.30	2.60	2.49	3.18	4.29	9.65	16.23	13.94	7.60	5.01	5.18	4.60	4.61	7.60	100.00



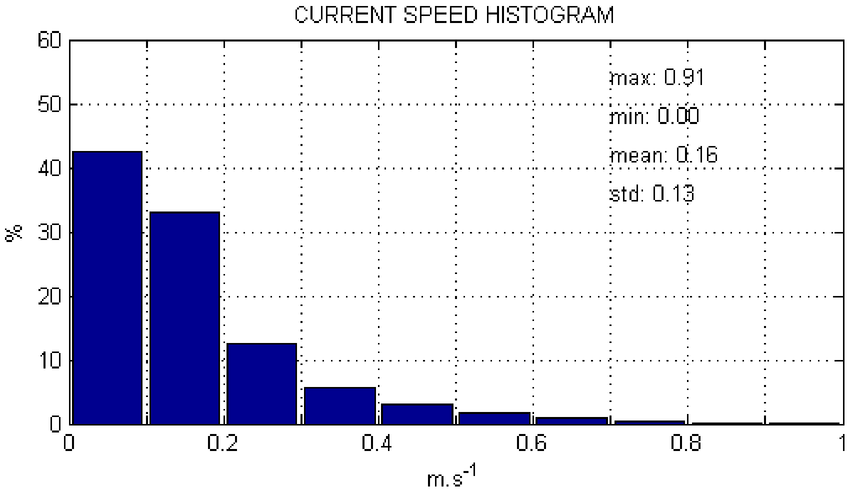


Figure 9: Summary plot of the 10m ADCP's current data at 1.0m.

5.1.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

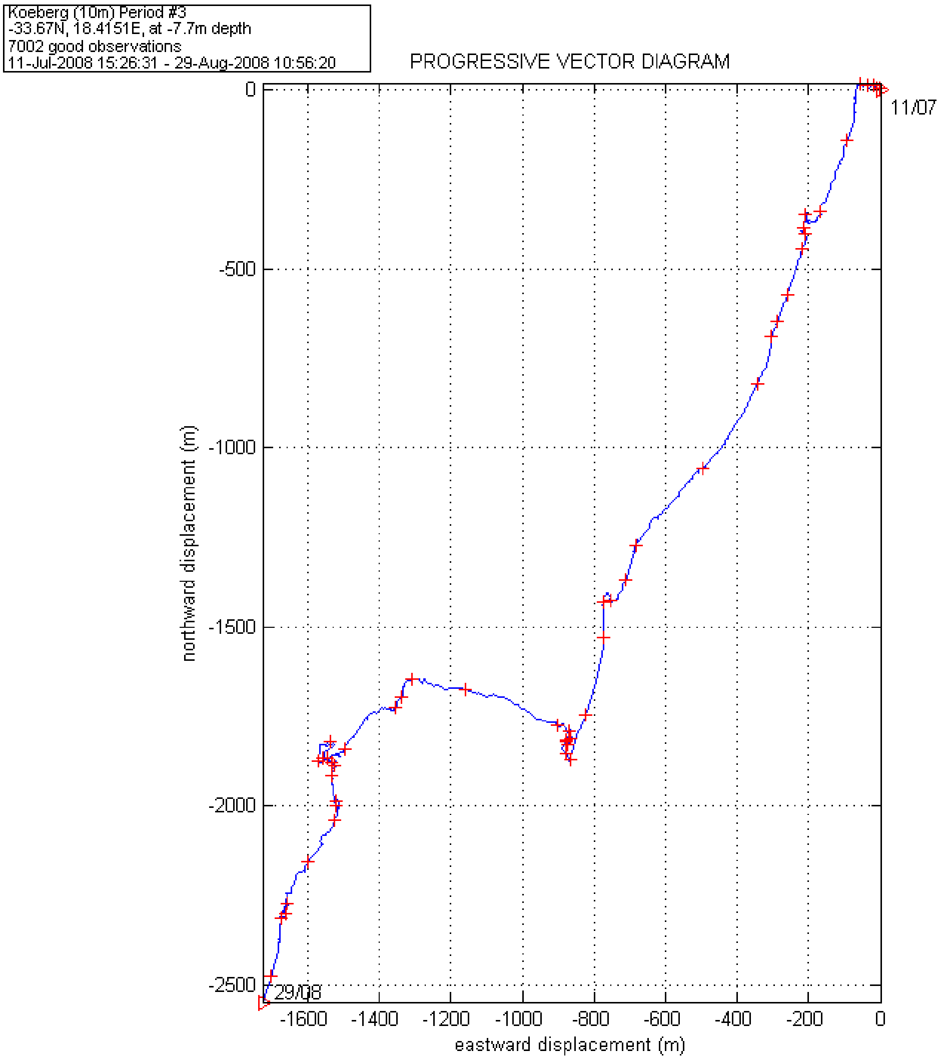


Figure 10: Progressive vector plot of current data at 7.7m.

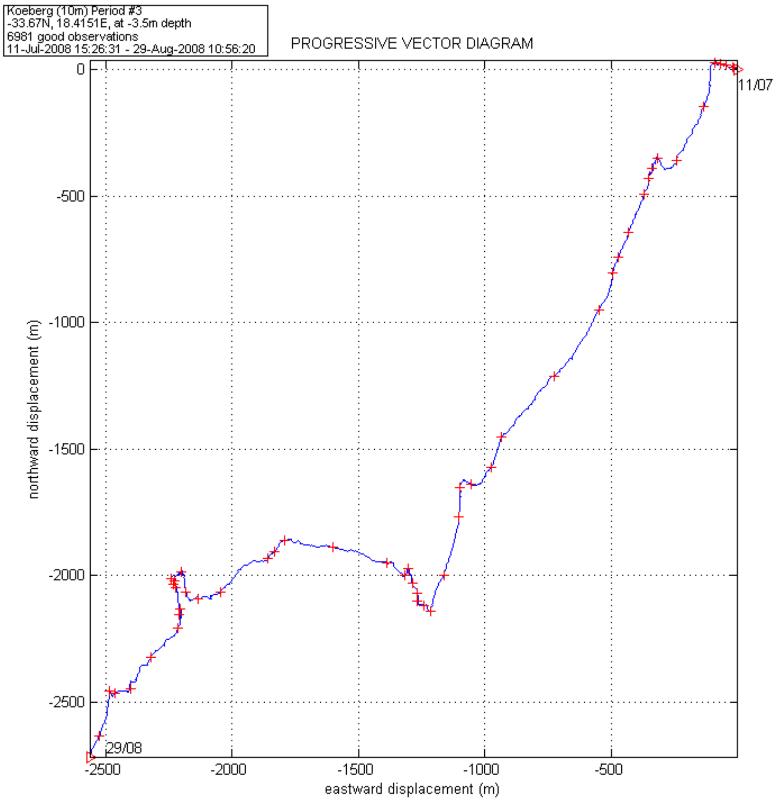


Figure 11: Progressive vector plot of current data at 3.5m.

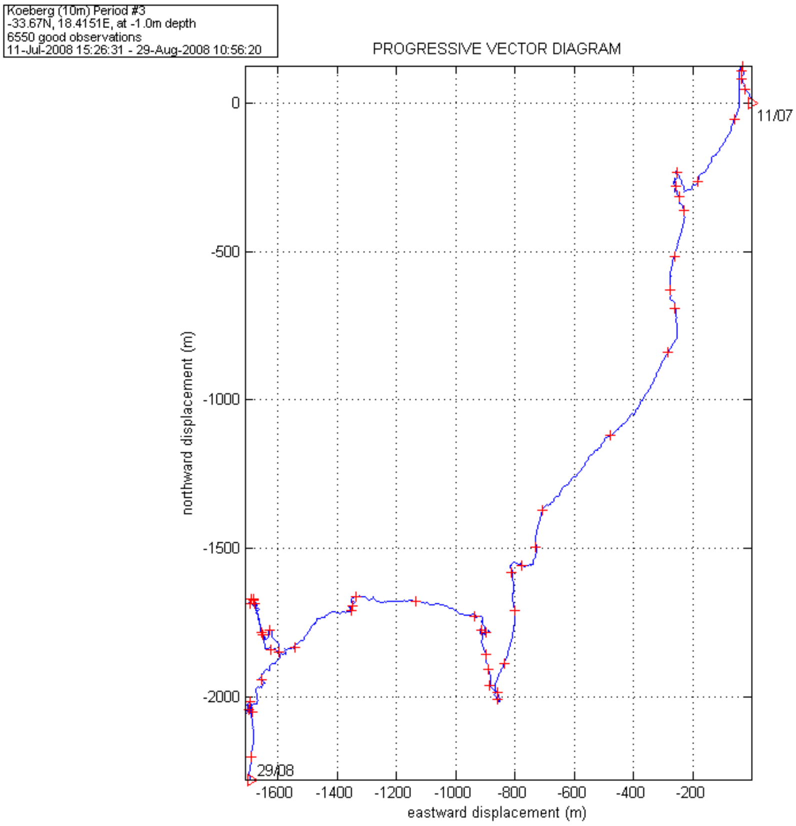


Figure 12: Progressive vector plot of current data at 1.0m.

5.1.2 Wave Data.

5.1.2.1 Hs and Tp summary plot

Figure 13 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.1.2.2 Hs and Dp summary plot

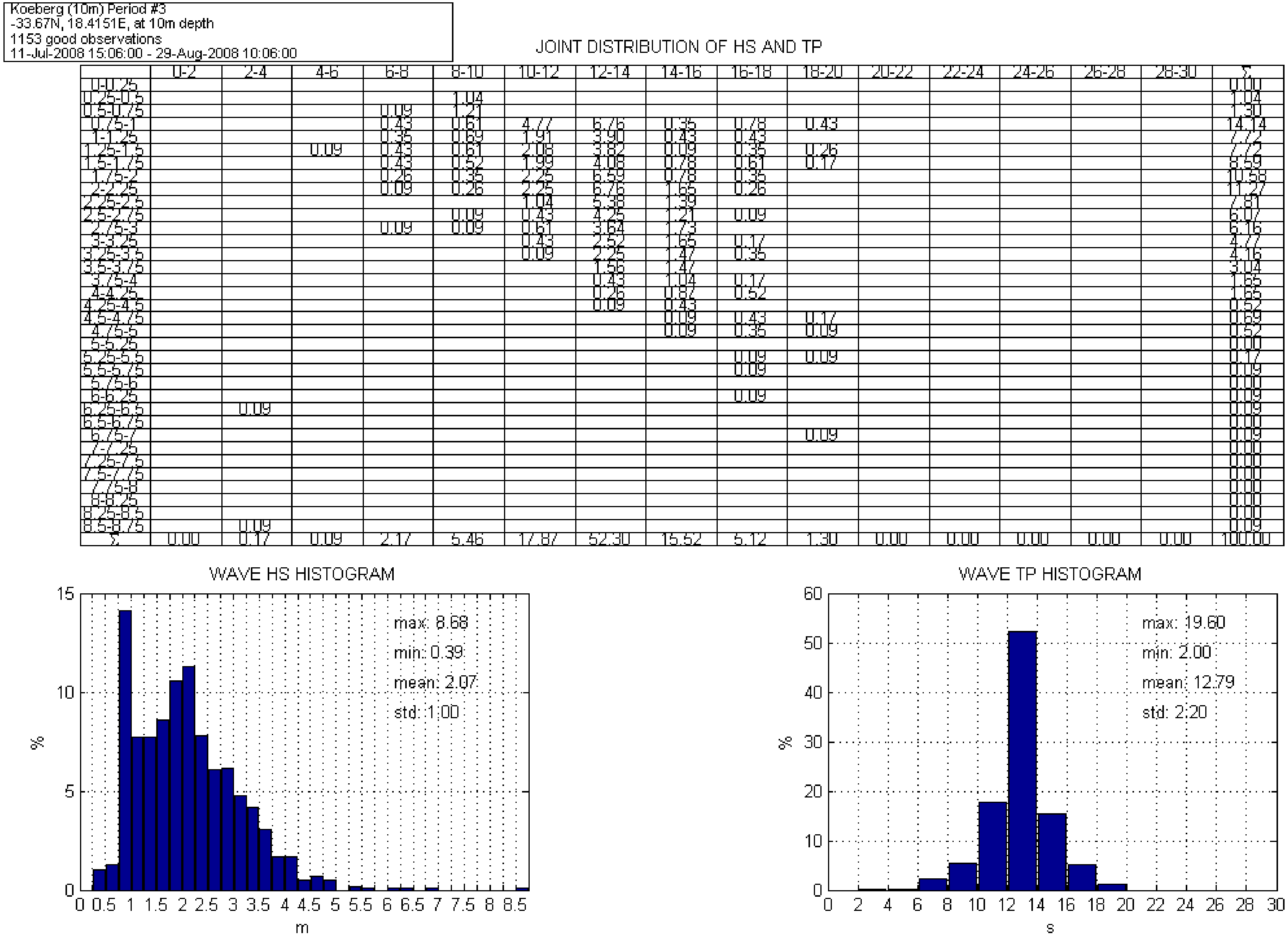
Figure 14 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.1.2.3 Tp and Dp summary plot

Figure 15 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

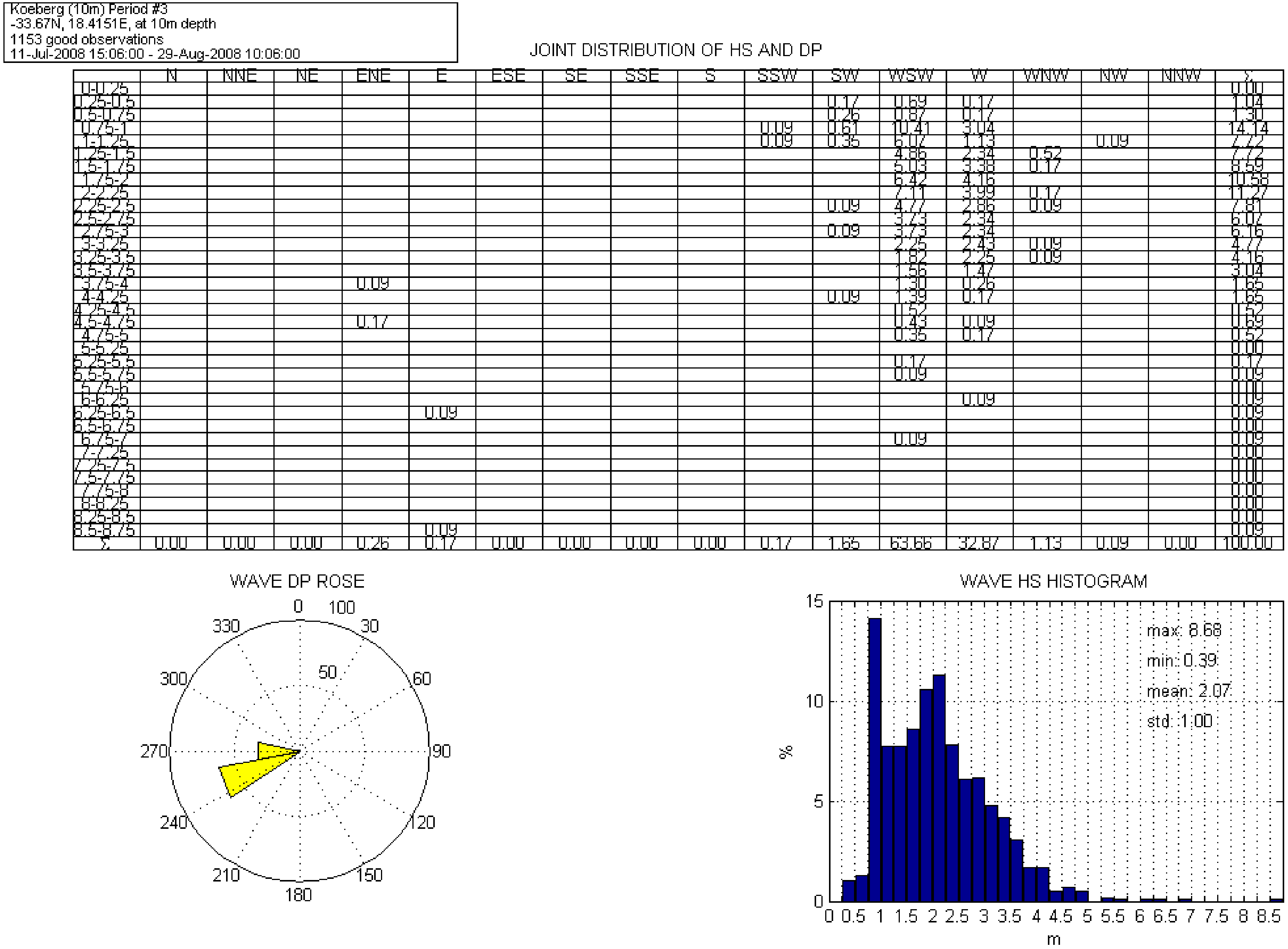


Koeberg (10m) Period #3
-33.67N, 18.4151E, at 10m depth
1153 good observations
11-Jul-2008 15:06:00 - 29-Aug-2008 10:06:00

JOINT DISTRIBUTION OF HS AND TP

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5					1.04											1.04
0.5-0.75				0.09	1.21											1.30
0.75-1				0.43	0.61	4.77	6.76	0.35	0.78	0.43						14.14
1-1.25				0.35	0.69	1.91	3.90	0.43	0.43							7.72
1.25-1.5			0.09	0.43	0.61	2.08	3.82	0.09	0.35	0.26						7.72
1.5-1.75				0.43	0.52	1.99	4.08	0.78	0.61	0.17						8.59
1.75-2				0.26	0.35	2.25	6.59	0.78	0.35							10.58
2-2.25				0.09	0.26	2.25	6.76	1.65	0.26							11.27
2.25-2.5						1.04	5.38	1.39								7.81
2.5-2.75					0.09	0.43	4.25	1.21	0.09							6.07
2.75-3				0.09	0.09	0.61	3.64	1.73								6.16
3-3.25						0.43	2.52	1.65	0.17							4.77
3.25-3.5						0.09	2.25	1.47	0.35							4.16
3.5-3.75							1.56	1.47								3.04
3.75-4							0.43	1.04	0.17							1.65
4-4.25							0.26	0.87	0.52							1.65
4.25-4.5							0.09	0.43								0.52
4.5-4.75								0.09	0.43	0.17						0.69
4.75-5								0.09	0.35	0.09						0.52
5-5.25																0.00
5.25-5.5									0.09	0.09						0.17
5.5-5.75									0.09							0.09
5.75-6																0.00
6-6.25									0.09							0.09
6.25-6.5		0.09														0.09
6.5-6.75																0.00
6.75-7										0.09						0.09
7-7.25																0.00
7.25-7.5																0.00
7.5-7.75																0.00
7.75-8																0.00
8-8.25																0.00
8.25-8.5																0.00
8.5-8.75		0.09														0.09
Σ	0.00	0.17	0.09	2.17	5.46	17.87	52.30	15.52	5.12	1.30	0.00	0.00	0.00	0.00	0.00	100.00

Figure 13: Summary plot of H_s and T_p.

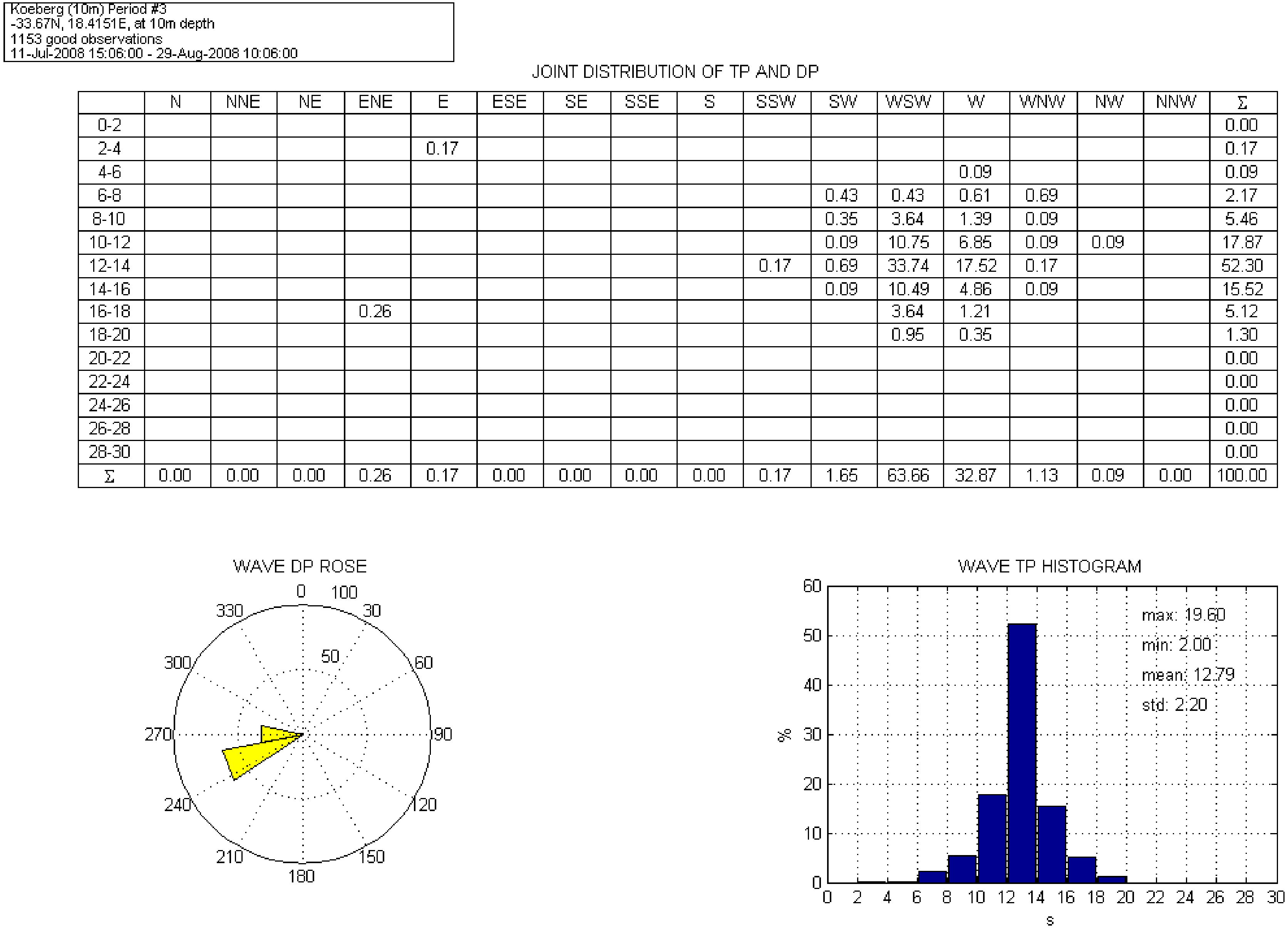


Koeberg (10m) Period #3
-33.67N, 18.4151E, at 10m depth
1153 good observations
11-Jul-2008 15:06:00 - 29-Aug-2008 10:06:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5											0.17	0.69	0.17				1.04
0.5-0.75											0.26	0.87	0.17				1.30
0.75-1										0.09	0.61	10.41	3.04				14.14
1-1.25										0.09	0.35	6.07	1.13		0.09		7.72
1.25-1.5												4.86	2.34	0.52			7.72
1.5-1.75												5.03	3.38	0.17			8.59
1.75-2												6.42	4.16				10.58
2-2.25												7.11	3.99	0.17			11.27
2.25-2.5											0.09	4.77	2.86	0.09			7.81
2.5-2.75												3.73	2.34				6.07
2.75-3											0.09	3.73	2.34				6.16
3-3.25												2.25	2.43	0.09			4.77
3.25-3.5												1.82	2.25	0.09			4.16
3.5-3.75												1.56	1.47				3.04
3.75-4				0.09								1.30	0.26				1.65
4-4.25											0.09	1.39	0.17				1.65
4.25-4.5												0.52					0.52
4.5-4.75				0.17								0.43	0.09				0.69
4.75-5												0.35	0.17				0.52
5-5.25																	0.00
5.25-5.5												0.17					0.17
5.5-5.75												0.09					0.09
5.75-6																	0.00
6-6.25													0.09				0.09
6.25-6.5					0.09												0.09
6.5-6.75																	0.00
6.75-7												0.09					0.09
7-7.25																	0.00
7.25-7.5																	0.00
7.5-7.75																	0.00
7.75-8																	0.00
8-8.25																	0.00
8.25-8.5																	0.00
8.5-8.75					0.09												0.09
Σ	0.00	0.00	0.00	0.26	0.17	0.00	0.00	0.00	0.00	0.17	1.65	63.66	32.87	1.13	0.09	0.00	100.00

Figure 14: Summary plot of H_s and D_p.



Koeberg (10m) Period #3
-33.67N, 18.4151E, at 10m depth
1153 good observations
11-Jul-2008 15:06:00 - 29-Aug-2008 10:06:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4					0.17												0.17
4-6													0.09				0.09
6-8											0.43	0.43	0.61	0.69			2.17
8-10											0.35	3.64	1.39	0.09			5.46
10-12											0.09	10.75	6.85	0.09	0.09		17.87
12-14										0.17	0.69	33.74	17.52	0.17			52.30
14-16											0.09	10.49	4.86	0.09			15.52
16-18				0.26								3.64	1.21				5.12
18-20												0.95	0.35				1.30
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.26	0.17	0.00	0.00	0.00	0.00	0.17	1.65	63.66	32.87	1.13	0.09	0.00	100.00

Figure 15: Summary plot of T_p and D_p.

5.1.2.4 Wave spectral plot

Figure 16 to Figure 18 display wave spectral plots for significant waves events. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

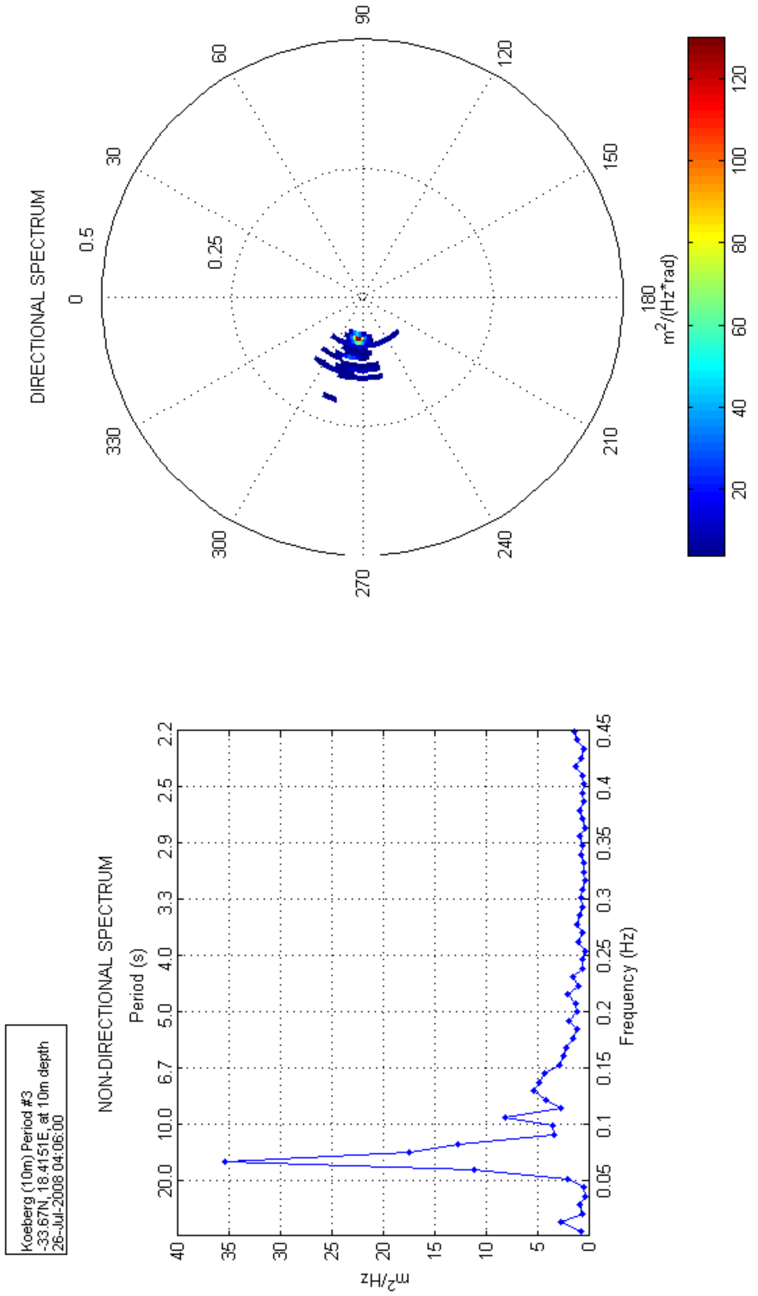


Figure 16: Wave spectra for 26th of July 2008 at 04:06:00.

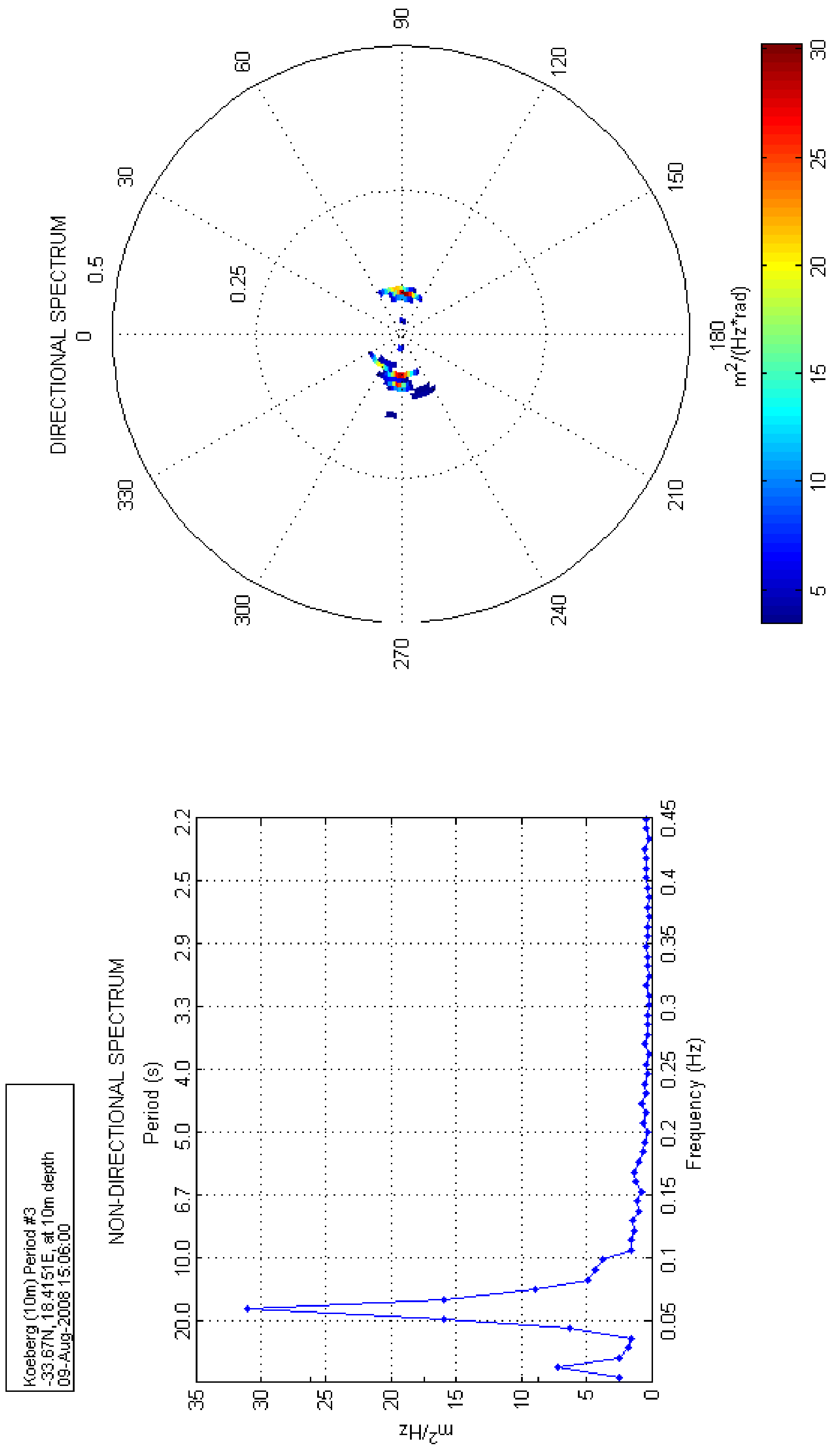


Figure 17: Wave spectra for 9th of August 2008 at 15:06:00.

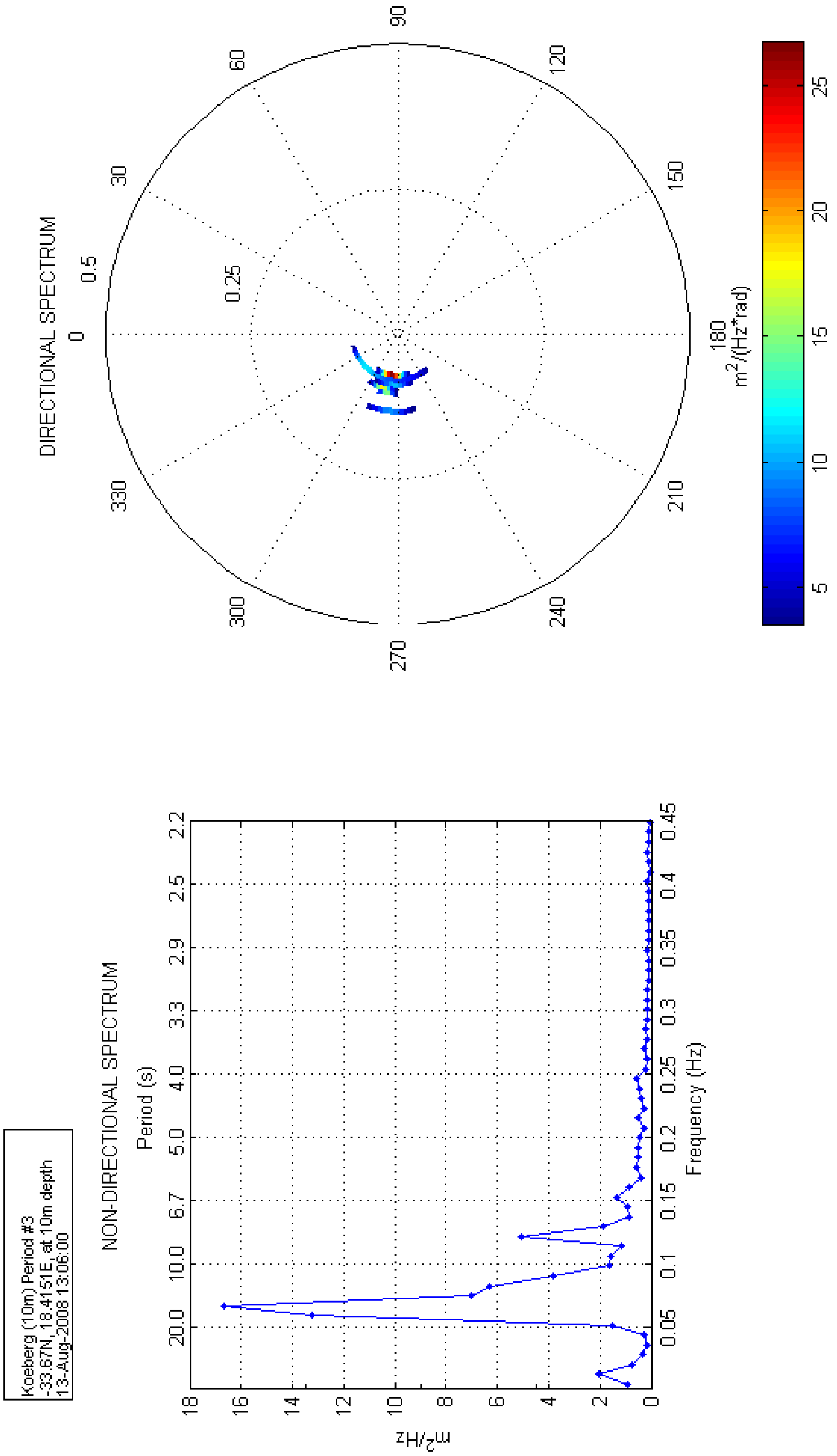


Figure 18: Wave spectra for 13th of August 2008 at 13:06:00.

5.2 30M ADCP

5.2.1 Current Data

5.2.1.1 Time series plot

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

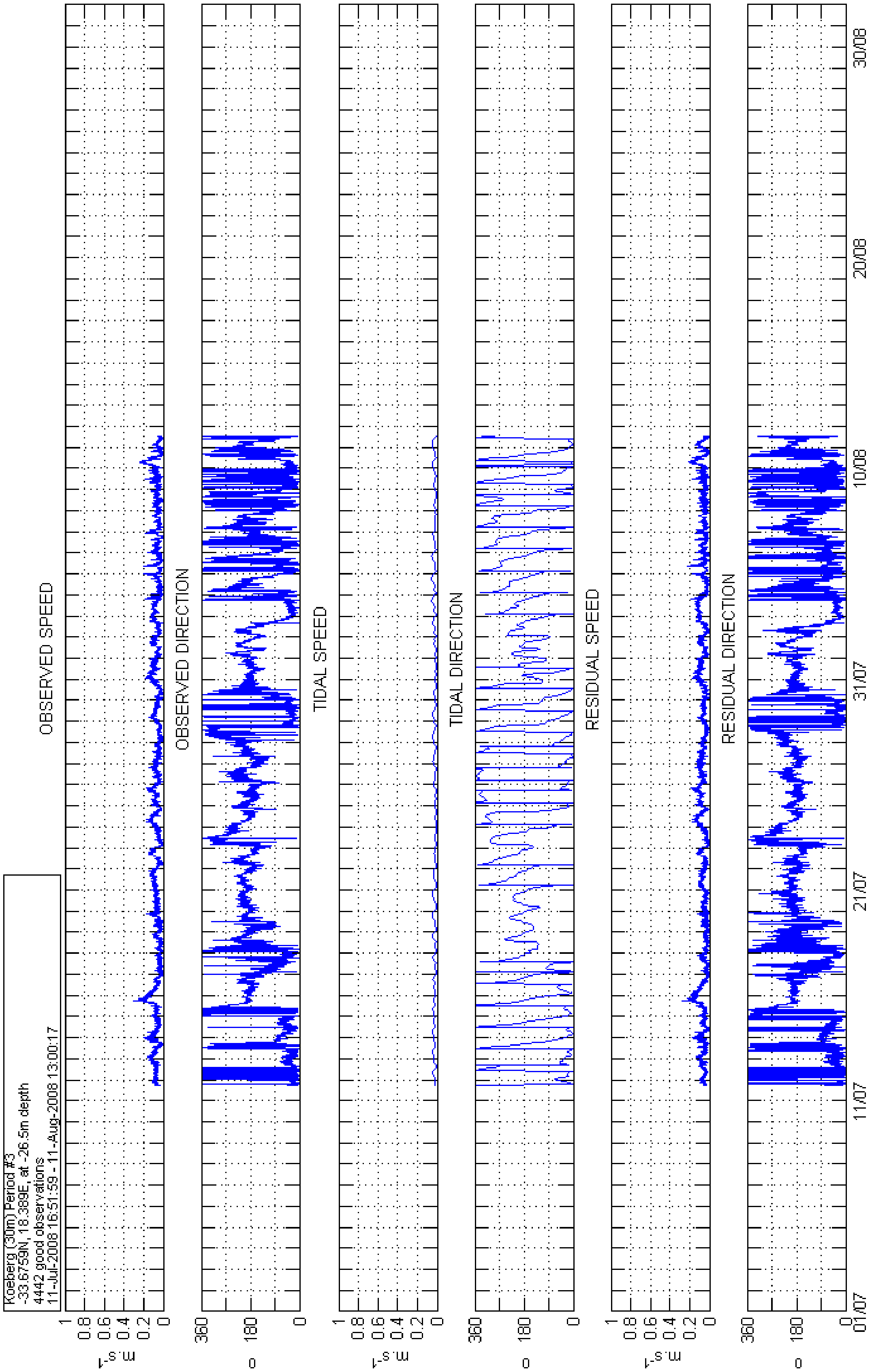


Figure 19: Time series plot of the 30m ADCP’s current data at 26.5m.

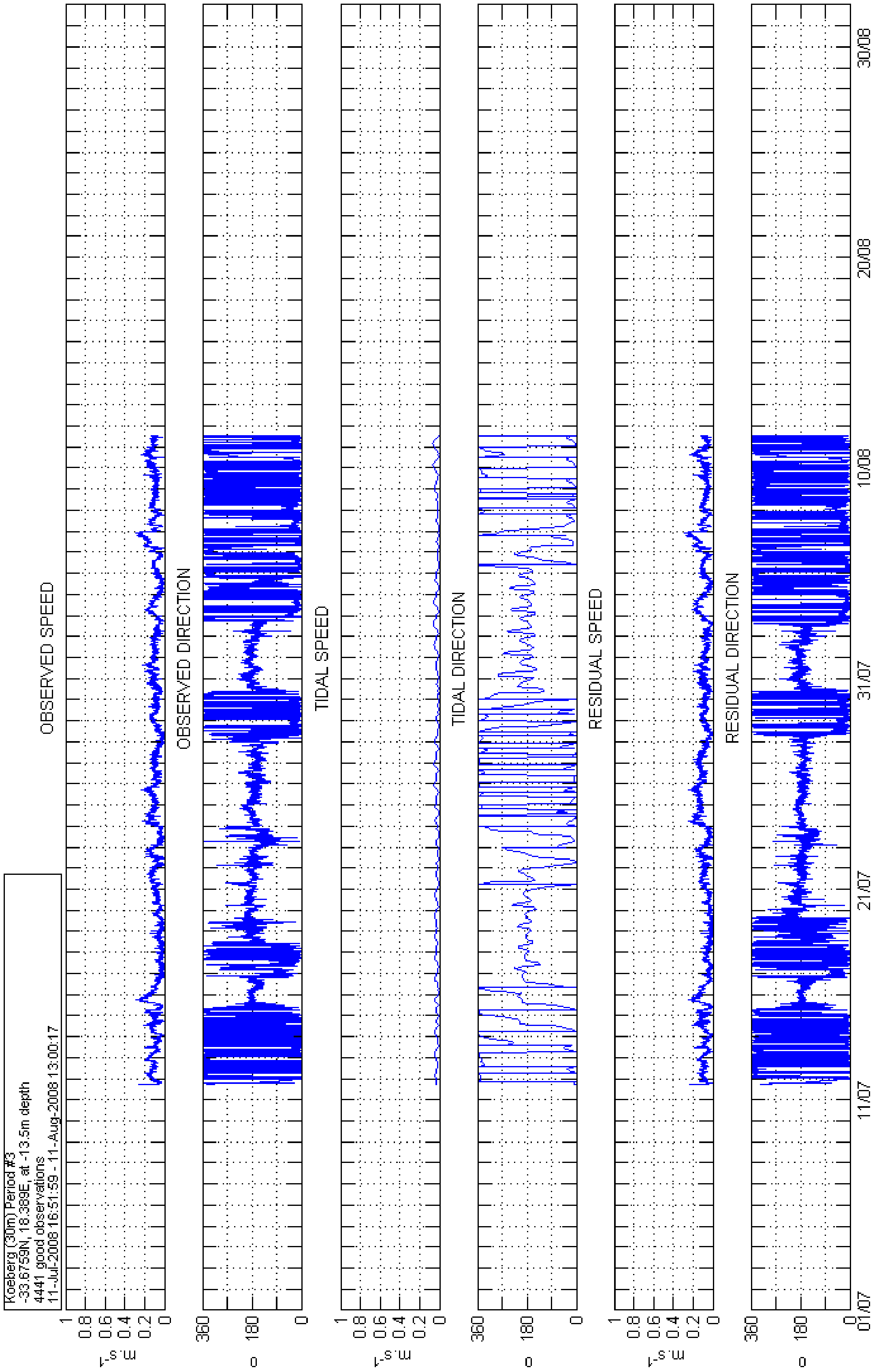


Figure 20: Time series plot of the 30m ADCP’s current data at 13.5m.

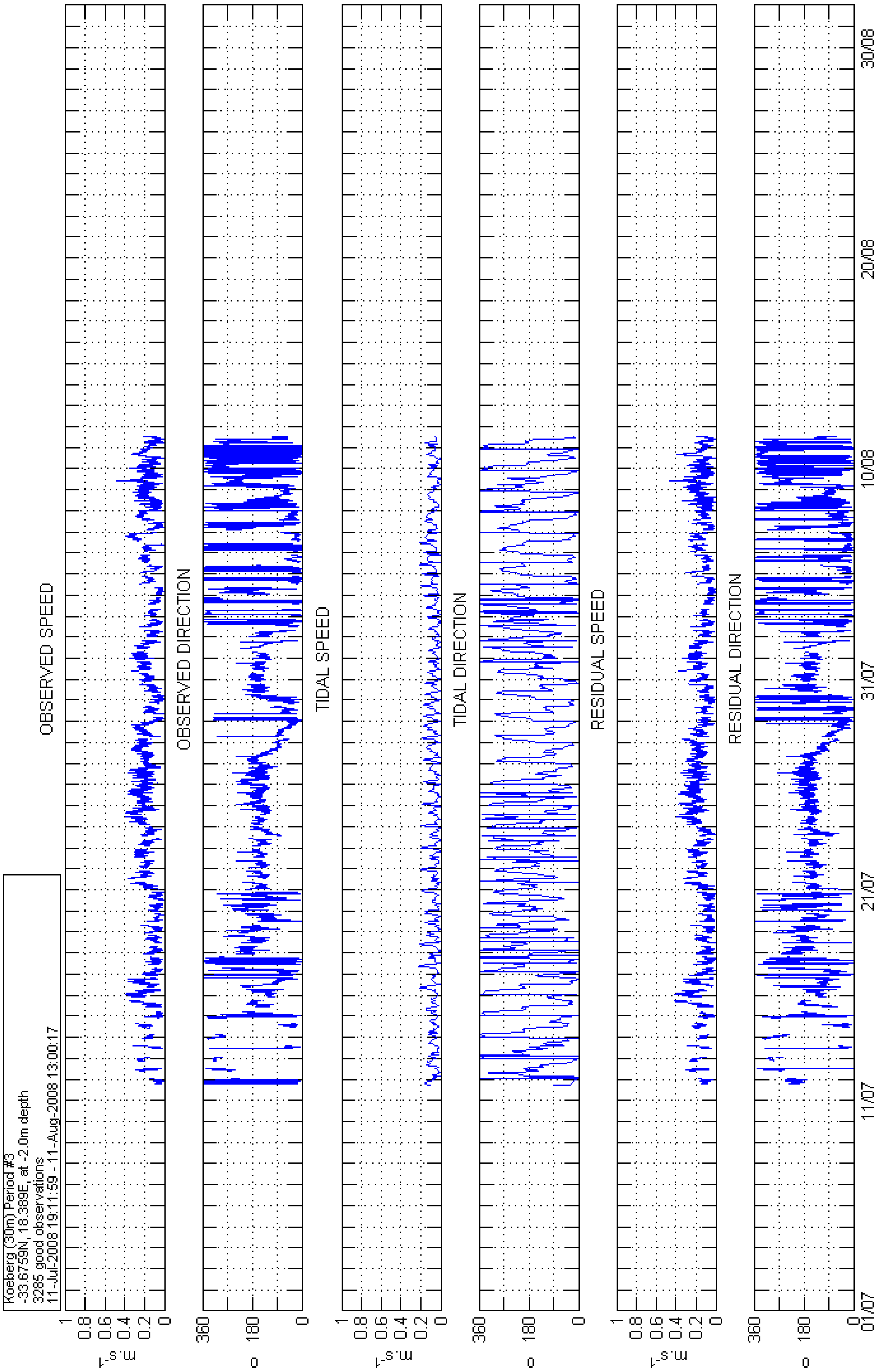


Figure 21: Time series plot of the 30m ADCP's current data at 2.0m.

5.2.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg (30m) Period #3
-33.6759N, 18.389E, at -26.5m depth
4442 good observations
11-Jul-2008 16:51:59 - 11-Aug-2008 13:00:17

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	5.36	7.81	6.84	4.21	4.03	2.84	4.12	6.73	10.33	10.83	6.12	3.51	2.23	1.71	3.29	2.95	82.91
0.1-0.2	0.56	1.73	1.53	1.33	1.15	0.16	0.16	1.49	4.34	2.70	0.92	0.09	0.07		0.02	0.16	16.41
0.2-0.3		0.02	0.20	0.02	0.02				0.27	0.11							0.65
0.3-0.4									0.02								0.02
0.4-0.5																	0.00
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	5.92	9.57	8.58	5.56	5.20	2.99	4.28	8.22	14.97	13.64	7.05	3.60	2.30	1.71	3.31	3.11	100.00

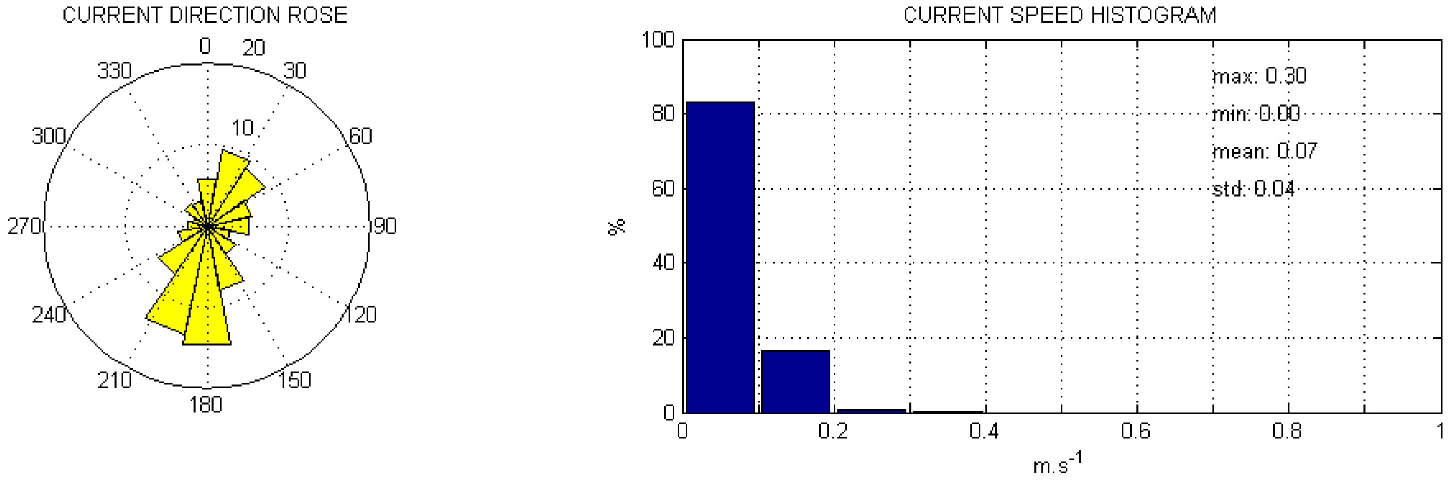


Figure 22: Summary plot of the 30m ADCP's current data at 26.5m.

Koeberg (30m) Period #3
-33.6759N, 18.389E, at -13.5m depth
4441 good observations
11-Jul-2008 16:51:59 - 11-Aug-2008 13:00:17

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	9.71	5.67	2.34	1.62	1.44	1.73	3.33	8.02	9.39	4.89	1.28	0.88	1.01	0.81	1.78	4.35	58.25
0.1-0.2	11.69	5.16	0.99	0.23	0.07	0.02	0.72	5.07	9.39	2.41	0.18	0.09	0.14	0.14	0.34	2.95	39.56
0.2-0.3	0.81	0.02						0.11	0.74	0.07			0.02	0.05	0.02	0.34	2.18
0.3-0.4																	0.00
0.4-0.5																	0.00
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	22.20	10.85	3.33	1.85	1.51	1.76	4.05	13.20	19.52	7.36	1.46	0.97	1.17	0.99	2.14	7.63	100.00

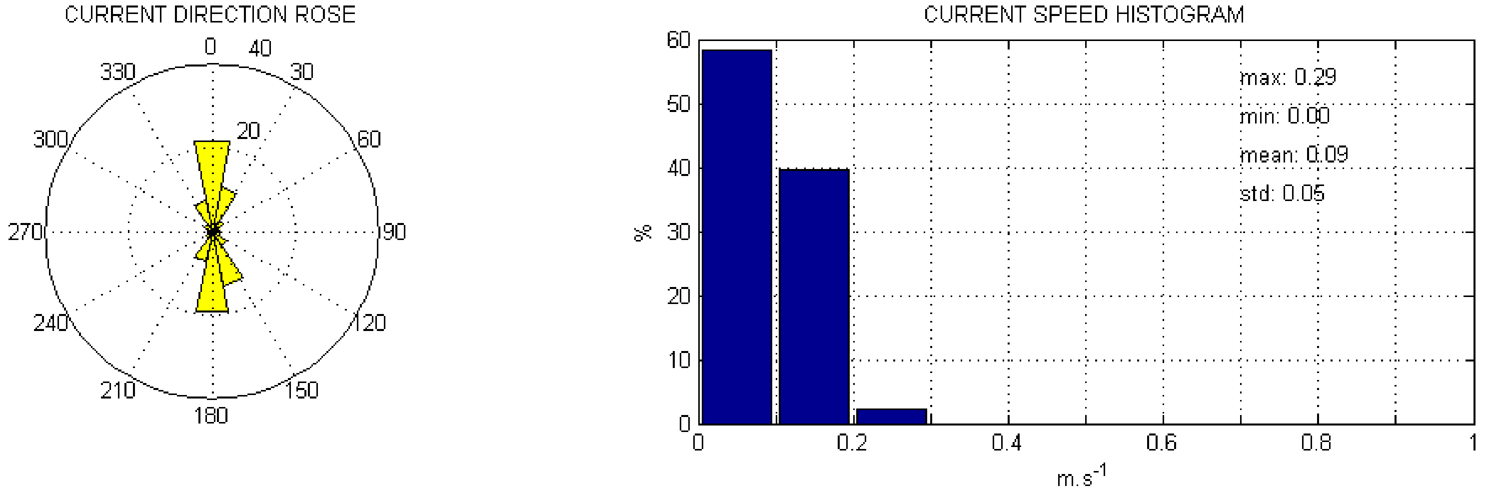
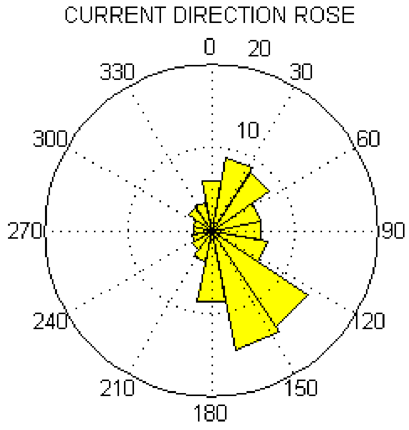


Figure 23: Summary plot of the 30m ADCP's current data at 13.5m.

Koeberg (30m) Period #3
-33.6759N, 18.389E, at -2.0m depth
3285 good observations
11-Jul-2008 19:11:59 - 11-Aug-2008 13:00:17

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	1.86	1.89	1.58	1.37	1.52	2.10	2.19	1.98	2.31	1.98	1.34	1.10	0.88	0.91	1.22	1.49	25.72
0.1-0.2	3.14	3.68	3.26	2.77	2.07	2.34	5.30	7.12	4.23	1.28	1.04	0.94	1.00	1.16	1.13	1.52	41.98
0.2-0.3	0.94	2.62	3.44	1.83	2.19	1.40	5.24	5.24	2.10	0.49	0.33	0.18	0.18	0.15	0.97	0.43	27.73
0.3-0.4	0.21	0.79	0.18	0.03	0.24	0.94	1.19	0.46	0.15	0.06	0.06	0.12			0.06	0.03	4.54
0.4-0.5													0.03				0.03
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	6.15	8.98	8.46	6.00	6.03	6.79	13.91	14.79	8.80	3.81	2.77	2.34	2.10	2.22	3.38	3.47	100.00



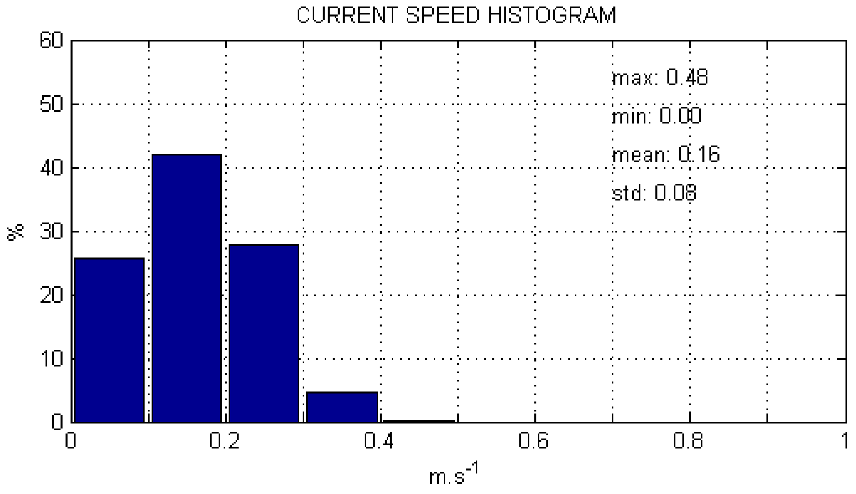


Figure 24: Summary plot of the 30m ADCP's current data at 2.0m.

5.2.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

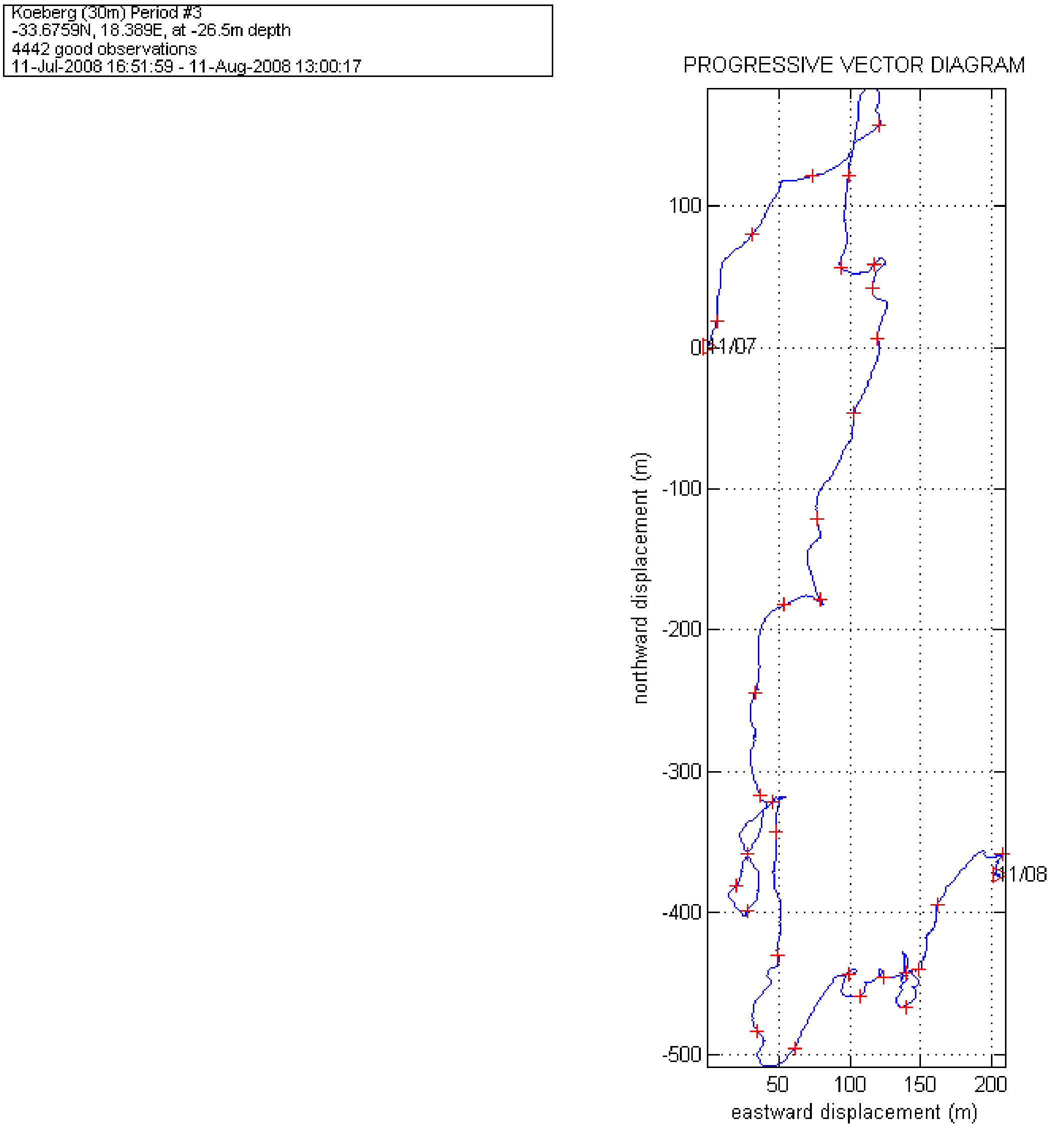

Koeberg (30m) Period #3
-33.6759N, 18.389E, at -26.5m depth
4442 good observations
11-Jul-2008 16:51:59 - 11-Aug-2008 13:00:17

Figure 25: Progressive vector plot of current data at 26.5m.

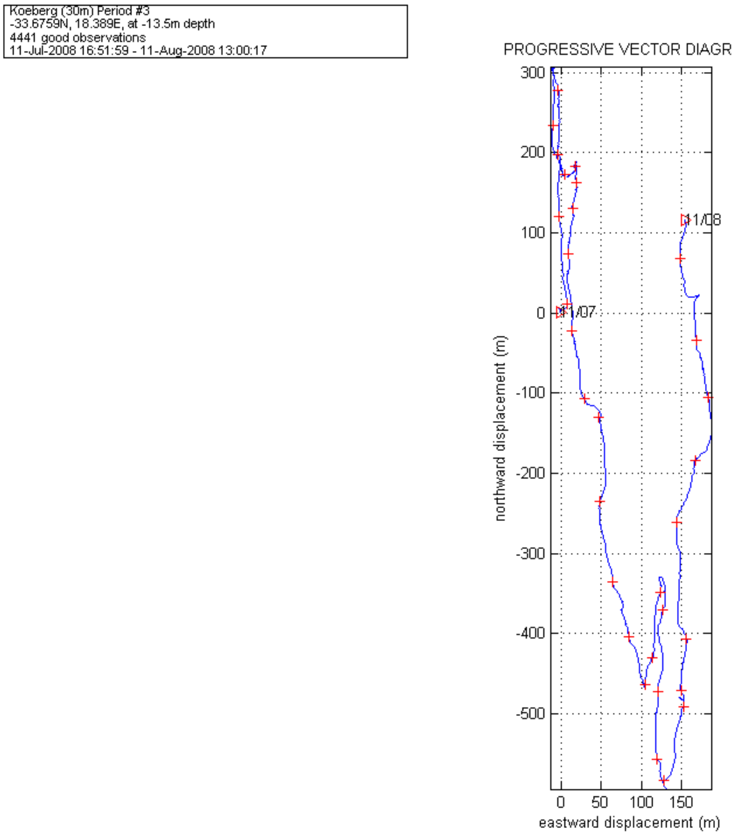


Figure 26: Progressive vector plot of current data at 13.5m.

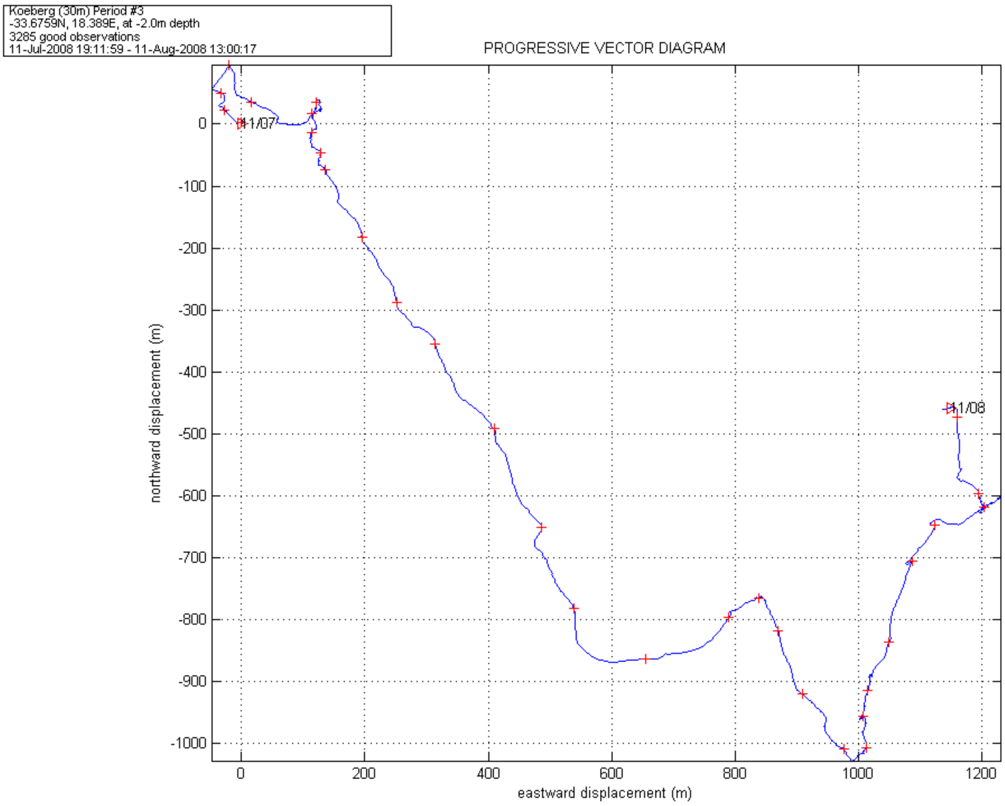


Figure 27: Progressive vector plot of current data at 2.0m.

5.2.2 Wave Data.

5.2.2.1 Hs and Tp summary plot

Figure 28 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.2.2.2 Hs and Dp summary plot

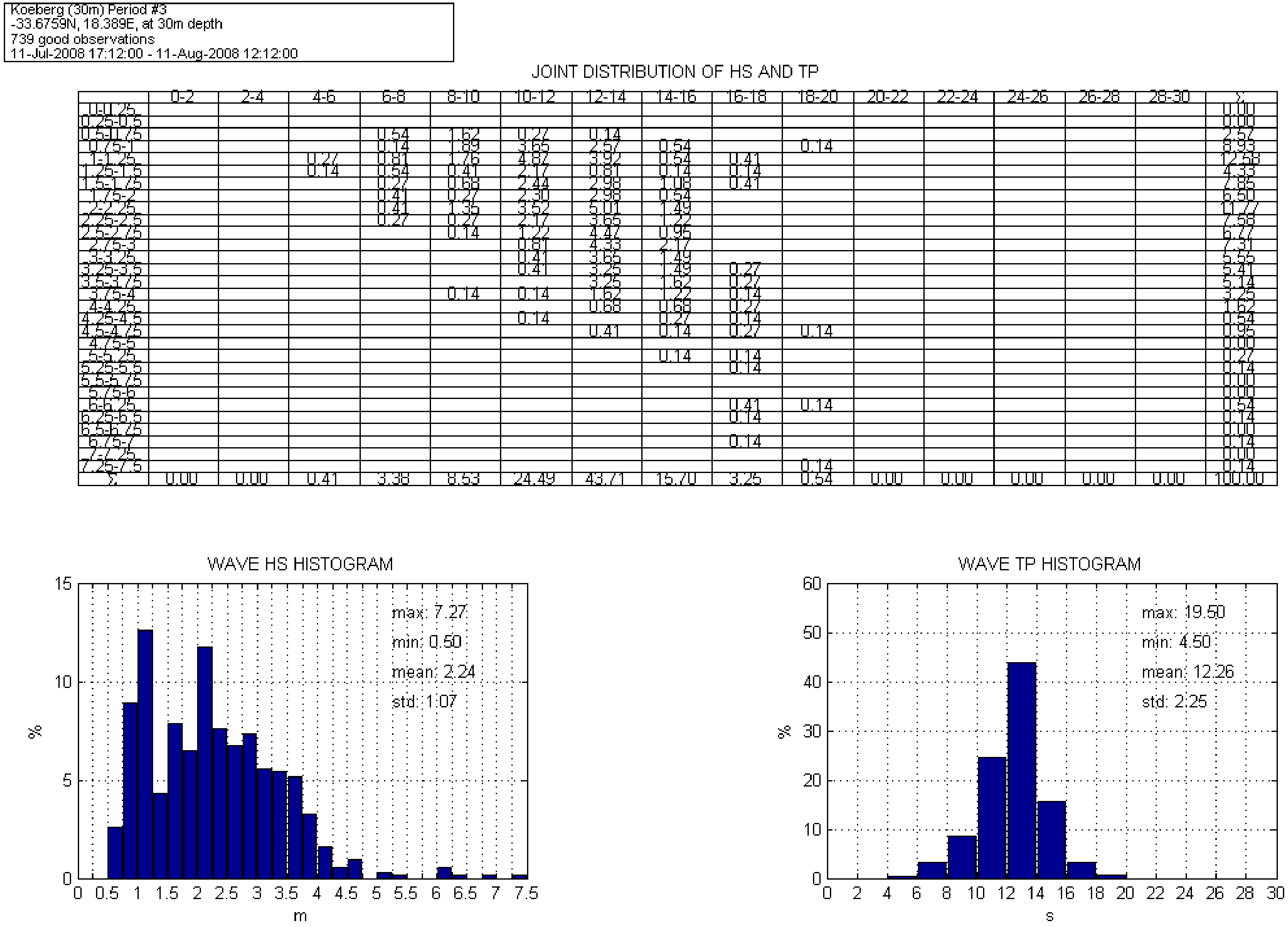
Figure 29 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.2.2.3 Tp and Dp summary plot

Figure 30 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.



Koeberg (30m) Period #3
-33.6759N, 18.389E, at 30m depth
739 good observations
11-Jul-2008 17:12:00 - 11-Aug-2008 12:12:00

JOINT DISTRIBUTION OF HS AND TP

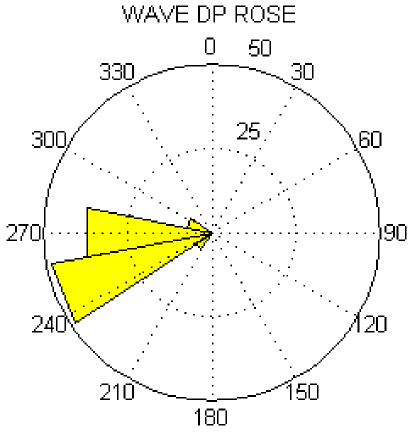
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5																0.00
0.5-0.75				0.54	1.62	0.27	0.14									2.57
0.75-1				0.14	1.89	3.65	2.57	0.54		0.14						8.93
1-1.25			0.27	0.81	1.76	4.87	3.92	0.54	0.41							12.58
1.25-1.5			0.14	0.54	0.41	2.17	0.81	0.14	0.14							4.35
1.5-1.75				0.27	0.68	2.44	2.98	1.08	0.41							7.85
1.75-2				0.41	0.27	2.30	2.98	0.54								6.50
2-2.25				0.41	1.35	3.52	5.01	1.49								11.77
2.25-2.5				0.27	0.27	2.17	3.65	1.22								7.58
2.5-2.75					0.14	1.22	4.47	0.95								6.77
2.75-3						0.81	4.33	2.17								7.31
3-3.25						0.41	3.65	1.49								5.55
3.25-3.5						0.41	3.25	1.49	0.27							5.41
3.5-3.75							3.25	1.62	0.27							5.14
3.75-4					0.14	0.14	1.62	1.22	0.14							3.25
4-4.25							0.68	0.68	0.27							1.62
4.25-4.5						0.14		0.27	0.14							0.54
4.5-4.75							0.41	0.14	0.27	0.14						0.95
4.75-5																0.00
5-5.25								0.14	0.14							0.27
5.25-5.5									0.14							0.14
5.5-5.75																0.00
5.75-6																0.00
6-6.25									0.41	0.14						0.54
6.25-6.5									0.14							0.14
6.5-6.75																0.00
6.75-7									0.14							0.14
7-7.25																0.00
7.25-7.5										0.14						0.14
Σ	0.00	0.00	0.41	3.38	8.53	24.49	43.71	15.70	3.25	0.54	0.00	0.00	0.00	0.00	0.00	100.00

Figure 28: Summary plot of H_s and T_p.

Koeberg (30m) Period #3
-33.6759N, 18.389E, at 30m depth
739 good observations
11-Jul-2008 17:12:00 - 11-Aug-2008 12:12:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5																	0.00
0.5-0.75											1.76	0.68		0.14			2.57
0.75-1											0.81	5.28	2.57	0.27			8.93
1-1.25											2.71	7.44	2.17	0.27			12.58
1.25-1.5											0.41	2.84	0.95	0.14			4.33
1.5-1.75												3.79	2.98	0.81	0.27		7.85
1.75-2												2.98	2.71	0.81			6.50
2-2.25												5.55	4.74	1.35	0.14		11.77
2.25-2.5												3.38	3.65	0.54			7.58
2.5-2.75											0.14	3.38	2.57	0.68			6.77
2.75-3												2.98	3.65	0.68			7.31
3-3.25											0.14	2.44	2.57	0.41			5.55
3.25-3.5												2.30	2.84	0.27			5.41
3.5-3.75												1.49	3.52	0.14			5.14
3.75-4												1.76	1.08	0.41			3.25
4-4.25												0.68	0.68	0.27			1.62
4.25-4.5												0.41	0.14				0.54
4.5-4.75												0.54	0.41				0.95
4.75-5																	0.00
5-5.25												0.14		0.14			0.27
5.25-5.5													0.14				0.14
5.5-5.75																	0.00
5.75-6																	0.00
6-6.25												0.27	0.27				0.54
6.25-6.5												0.14					0.14
6.5-6.75																	0.00
6.75-7												0.14					0.14
7-7.25																	0.00
7.25-7.5													0.14				0.14
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.95	48.58	37.75	7.31	0.41	0.00	100.00



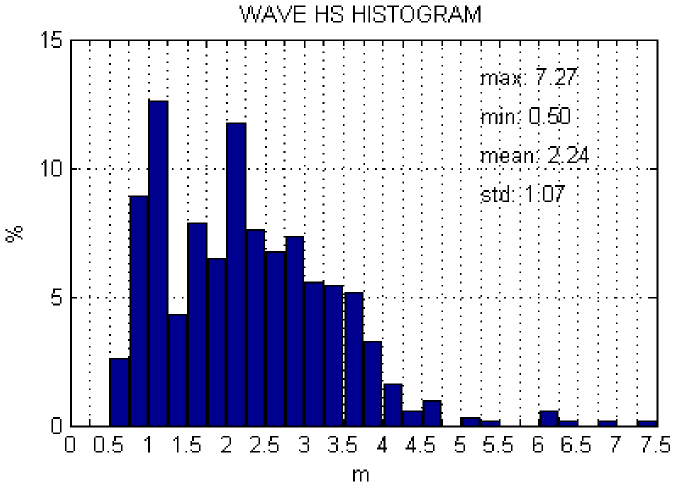
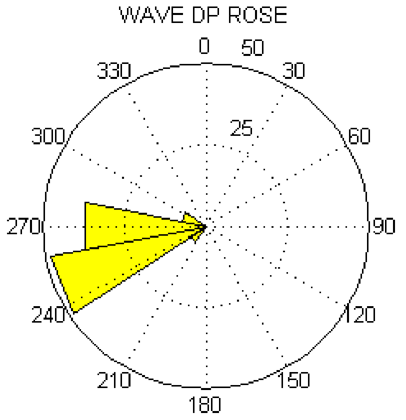


Figure 29: Summary plot of H_s and D_p.

Koeberg (30m) Period #3
-33.6759N, 18.389E, at 30m depth
739 good observations
11-Jul-2008 17:12:00 - 11-Aug-2008 12:12:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4																	0.00
4-6											0.14	0.27					0.41
6-8											1.22	1.35	0.14	0.54	0.14		3.38
8-10											2.03	4.74	0.95	0.81			8.53
10-12											1.35	11.23	9.47	2.17	0.27		24.49
12-14											1.08	20.57	18.67	3.38			43.71
14-16											0.14	9.07	6.22	0.27			15.70
16-18												1.35	1.76	0.14			3.25
18-20													0.54				0.54
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.95	48.58	37.75	7.31	0.41	0.00	100.00



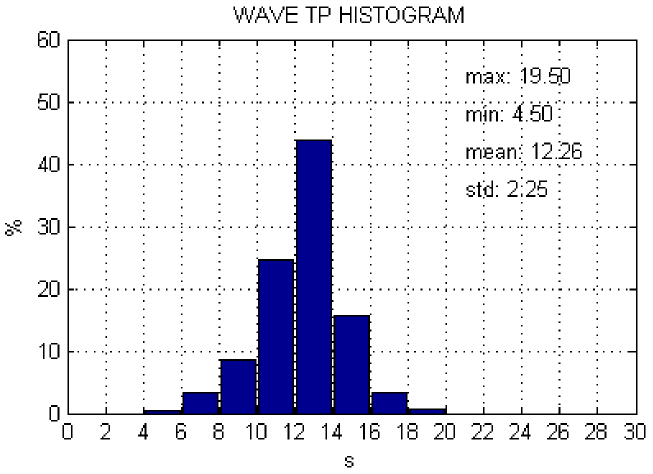


Figure 30: Summary plot of T_p and D_p.

5.2.2.4 Wave spectral plot

Figure 31 to Figure 33 display wave spectral plots for significant waves events. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

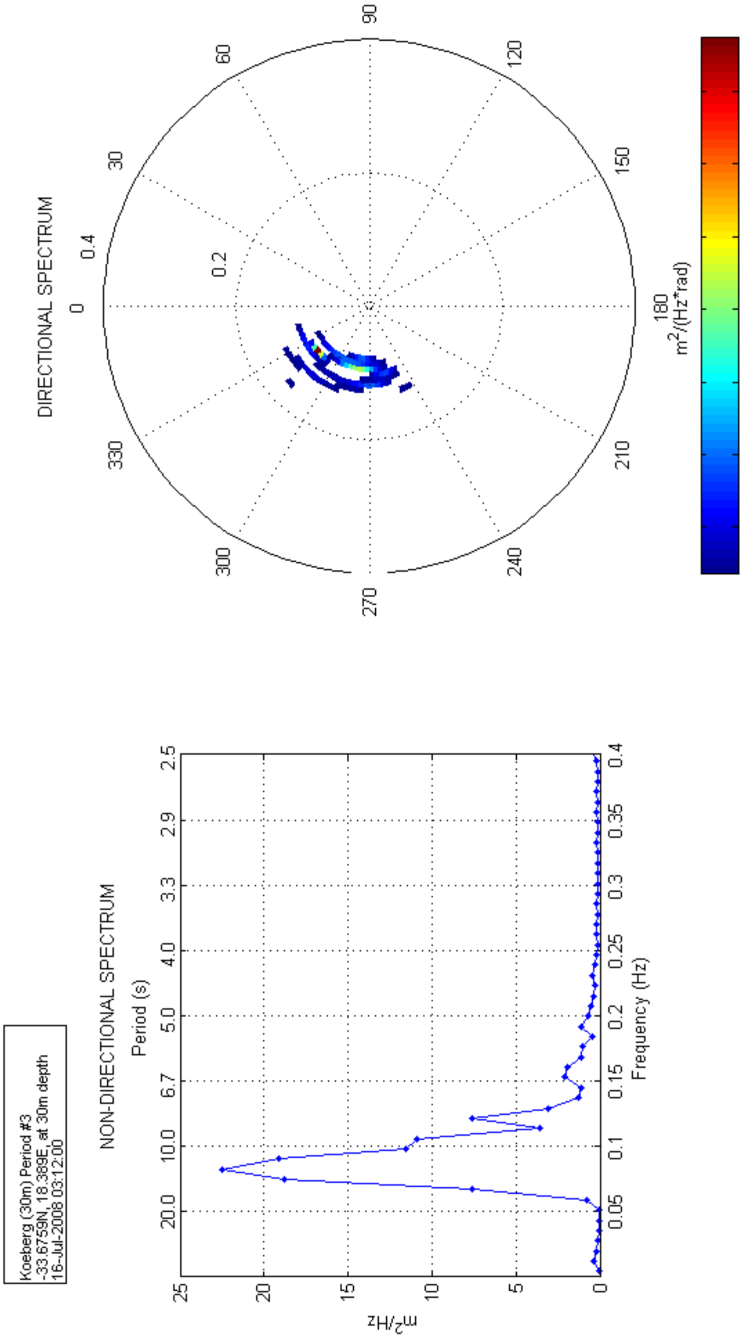


Figure 31: Wave spectra for 16th of July 2008 at 03:12:00.

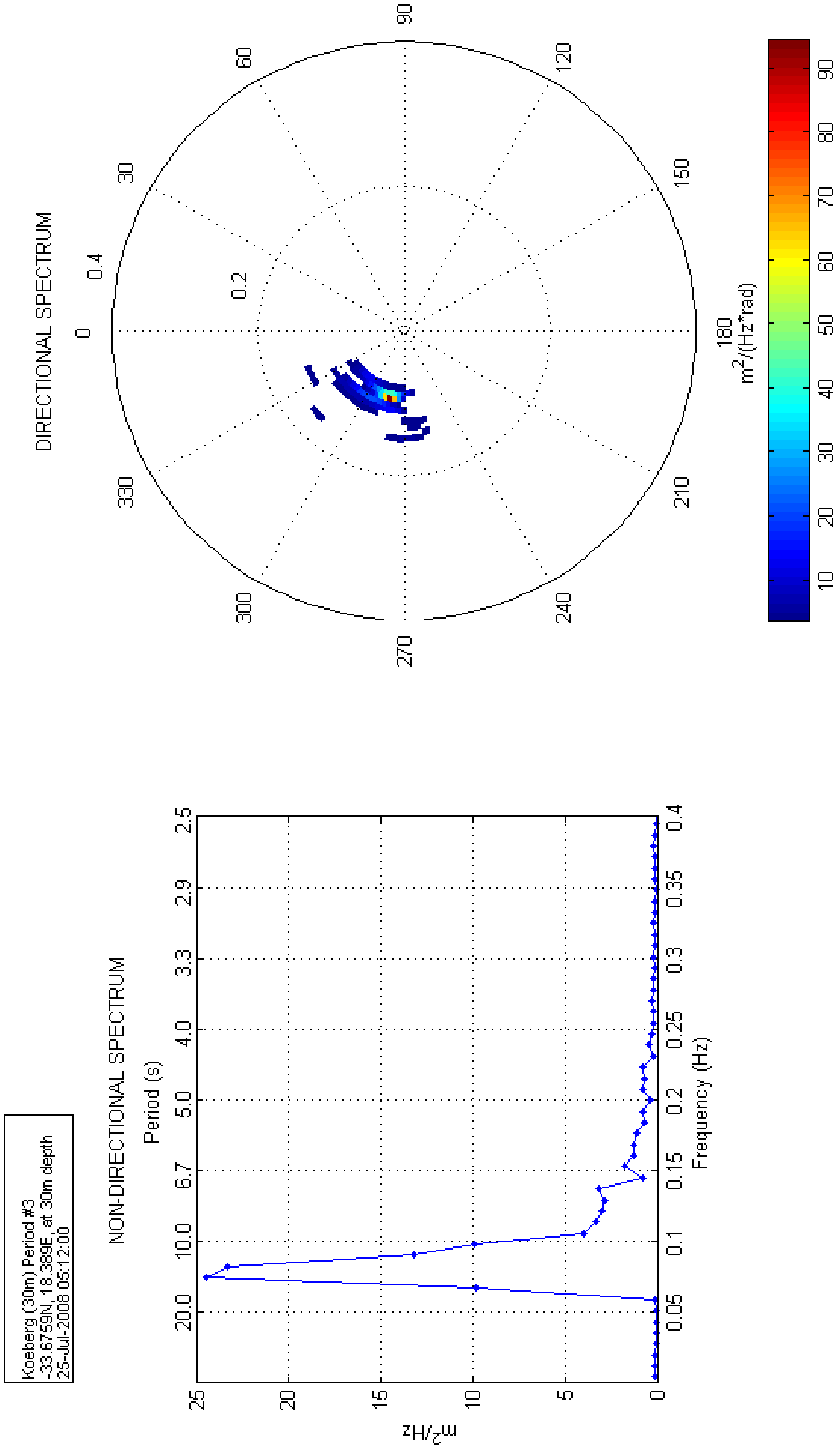


Figure 32: Wave spectra for 25th of July 2008 at 05:12:00.

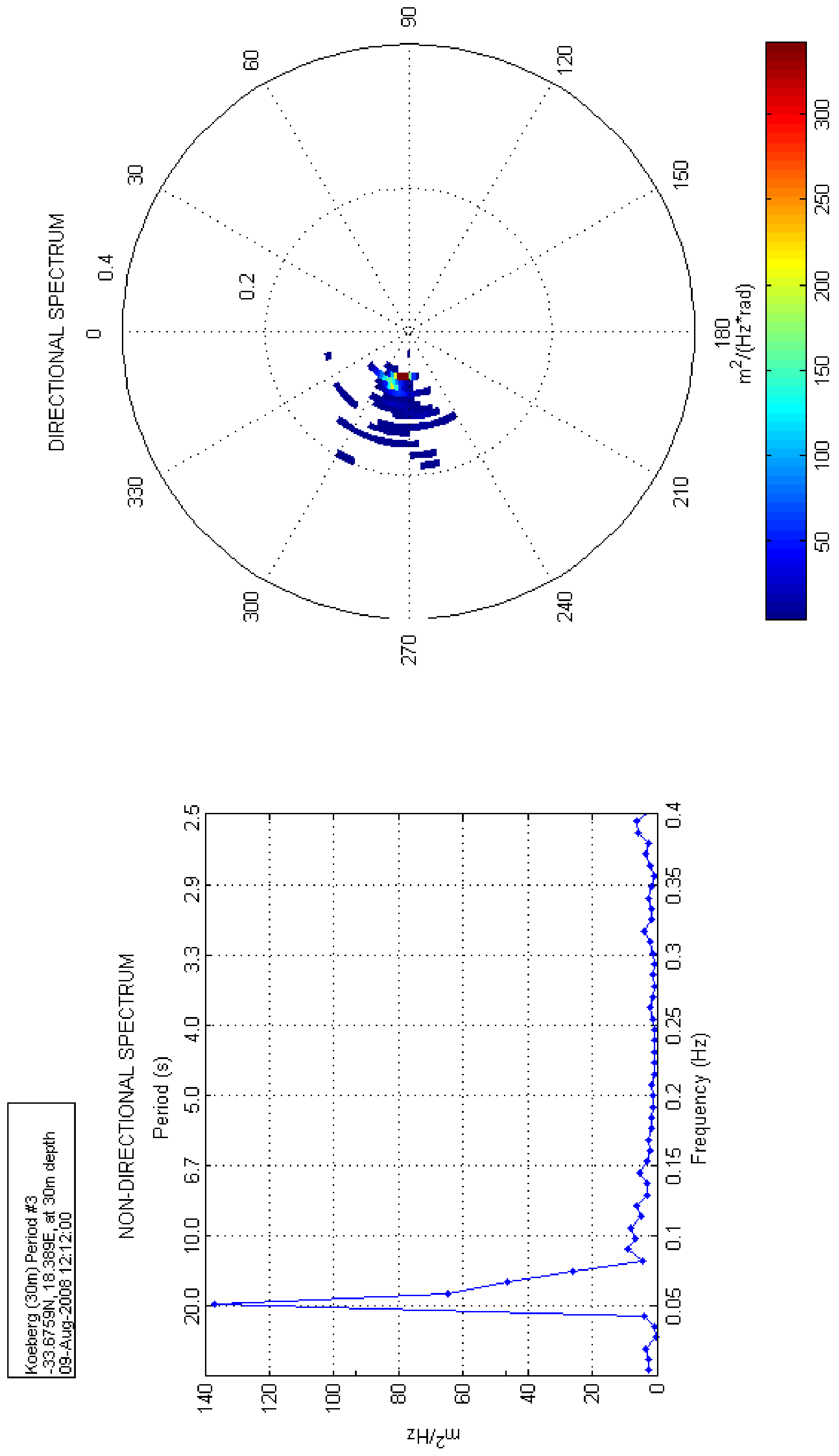


Figure 33: Wave spectra for 9th of August 2008 at 12:12:00.

5.3 COMPARISON PLOTS

5.3.1 Hs, Tp and Dp time series plots for 10m and 30m ADCPs.

Figure 34 displays a time series plot of the main wave parameters:

- The first (upper) panel is of the significant wave height (Hs).
- The second panel is of the peak period (Tp).
- The third panel is of the peak wave direction (Dp).

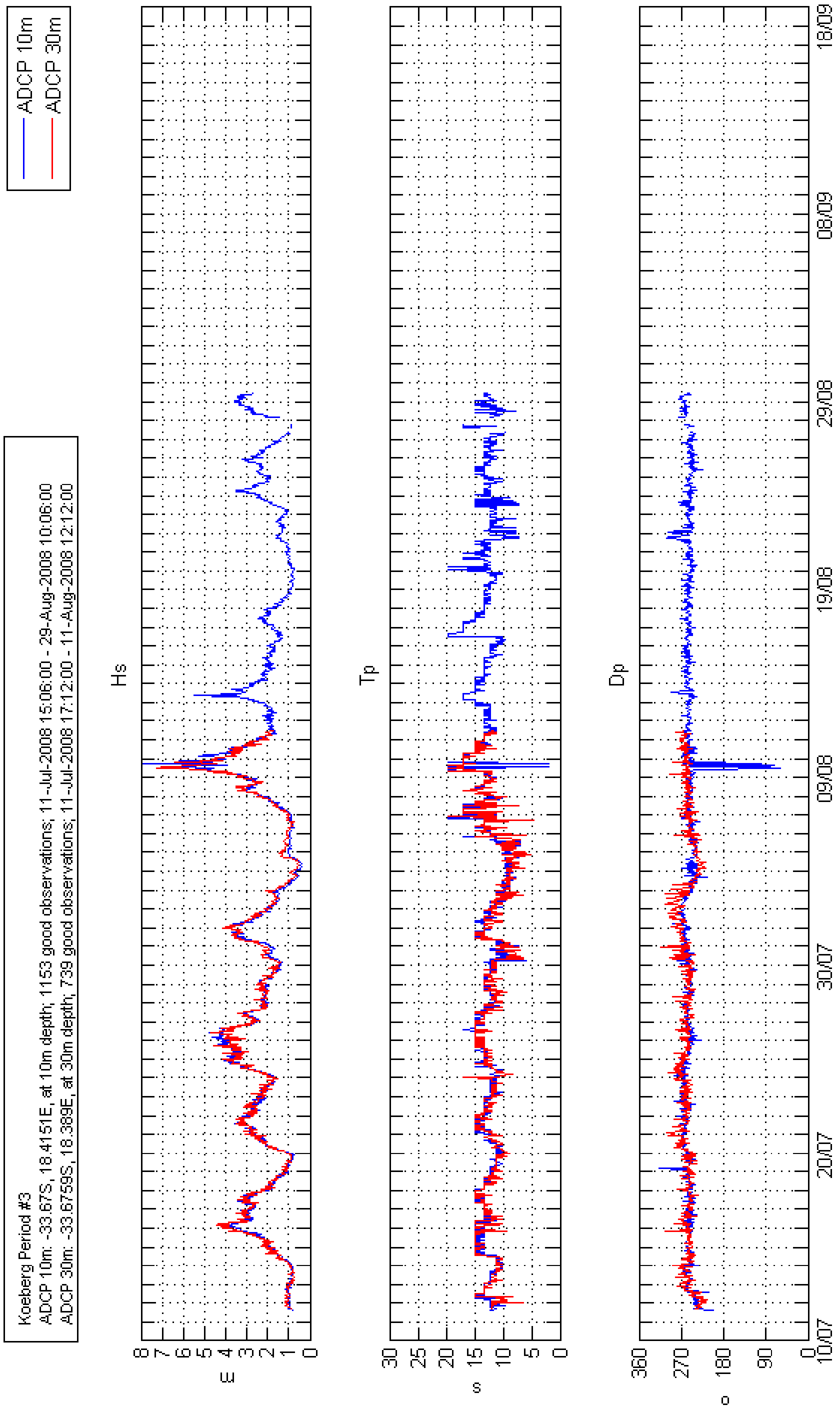


Figure 34: Wave Hs, Tp, and Dp for 10m and 30m ADCP.

5.3.2 Water properties: RBR-CT loggers, Thermister String and ADCPs temperature sensors.

Figure 35 displays a time series plot, which consists of:

- The first panel is of the observed water temperature from surface and bottom RBR loggers, 4 nodes of the Thermister string as well as ADCP temperature sensor against time.
- The second panel is of the derived salinity from the two RBR loggers against time.

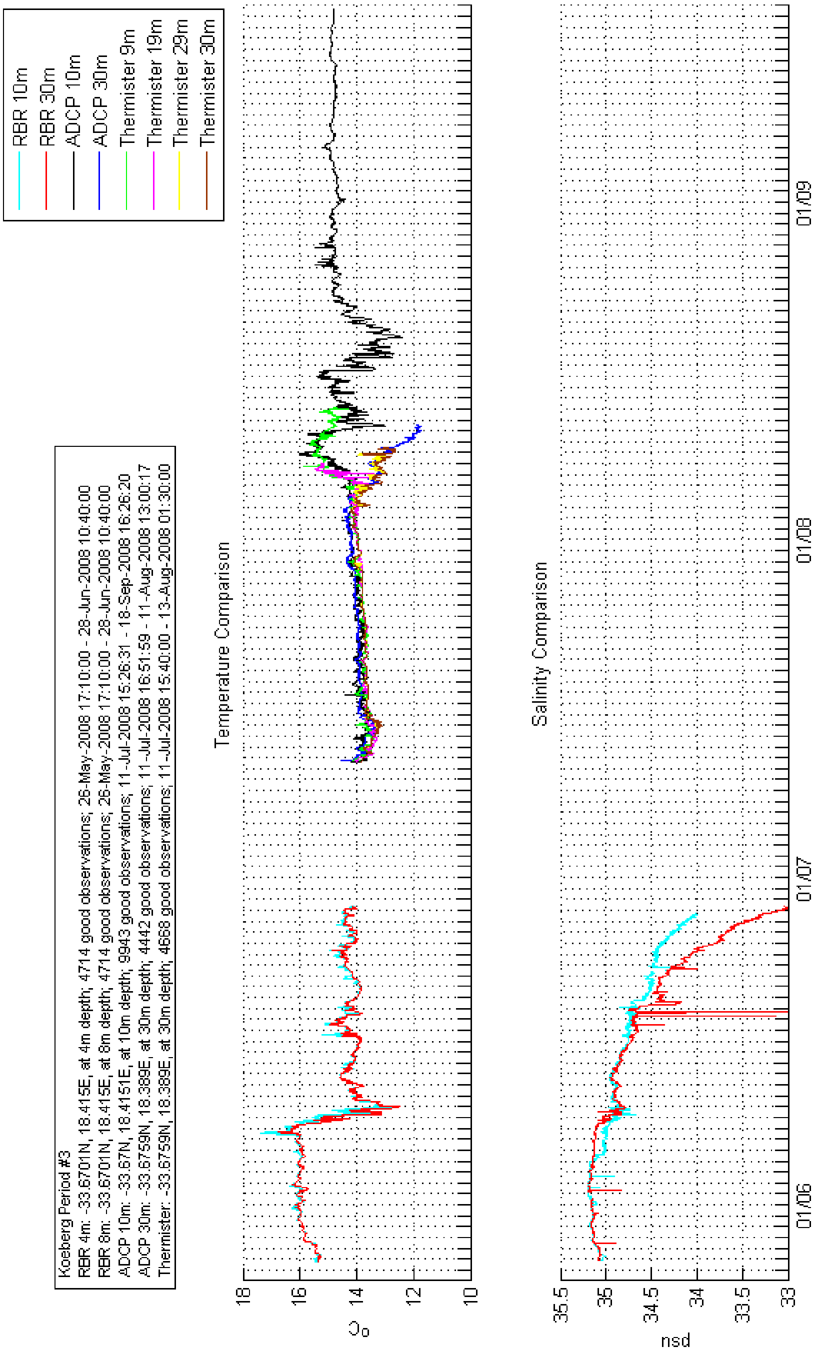


Figure 35: Time series of temperature and salinity from the RBR logger and ADCPs.

5.4 WATER SAMPLES.

Analysis of water samples were undertaken by the CSIR and results are presented as an appendage.

6. DISCUSSION

The third set of oceanographic data collected at Koeberg for the period between May 26th and September 21st 2008 has been presented in this report. The measurements taken fall within a larger dataset being compiled to assist a preliminary safety survey of multiple sites around the South African coast reports for Eskom.

At the Koeberg site, 2 600 kHz ADCPs, 2 RBR-CT loggers and 1 Thermister string with 4 channels have been deployed to measure currents, waves and water temperature and salinity. The ADCPs are fixed on a frame at ~10m and ~30m. The RBR loggers are moored at ~4m and ~8m below the surface. The Thermister string is deployed at the 30m site with nodes at 30m, 29m, 19m and 9m below the surface. The third recovery of the data was undertaken in 4 parts. Water samples were collected 3 times and recovery of 2 biofouling plates was undertaken.

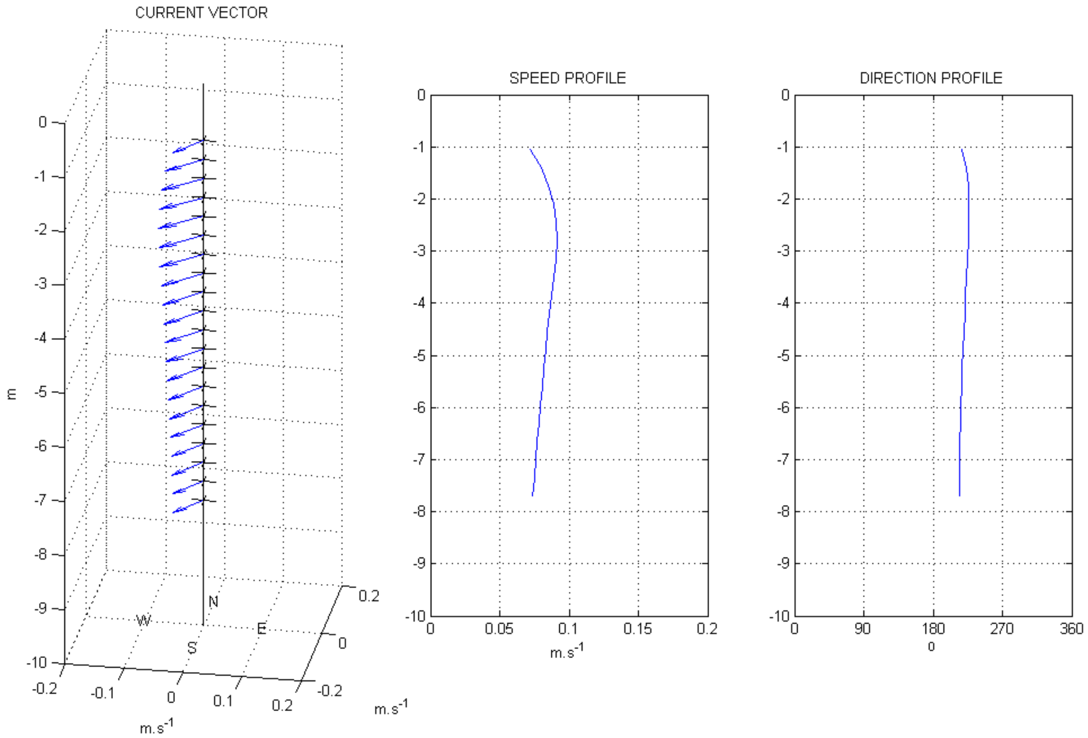


Figure 36: Mean profile plot for 10m ADCP.

The average surface current speed at the 10m site was ~0.16ms^{-1}, decreasing to ~0.15ms^{-1} at ~7m depth. The flow throughout the water column was predominantly towards the South-SouthWest. The mean current profile plot, presented in Figure 36, shows the gradual decrease in the vector mean speed.

Wave measurements indicated that, over the period of time, the average significant wave height was 2.07m, with a wave period of 12.79s and mean direction to W/WSW.

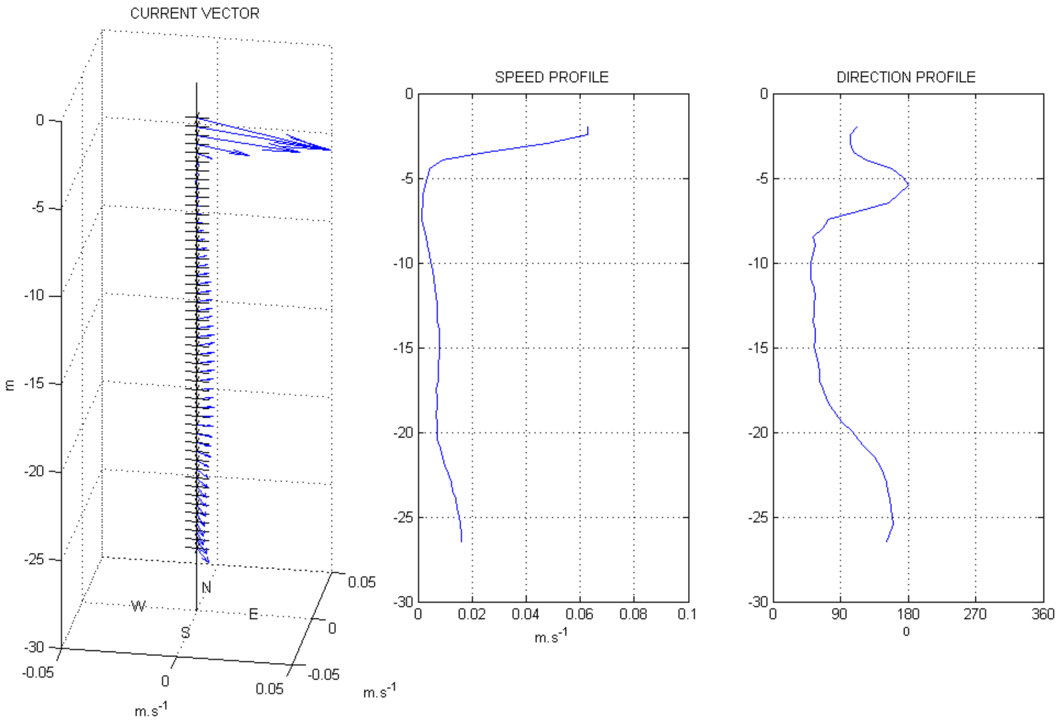


Figure 37: Mean profile plot for 30m ADCP.

The average surface current speed at the 30m site was ~0.16ms^{-1}, decreasing to ~0.07ms^{-1} at ~26.5m depth. The flow throughout the water column was wariable. The mean current profile plot, presented in Figure 37, shows the gradual decrease in the vector mean speed.

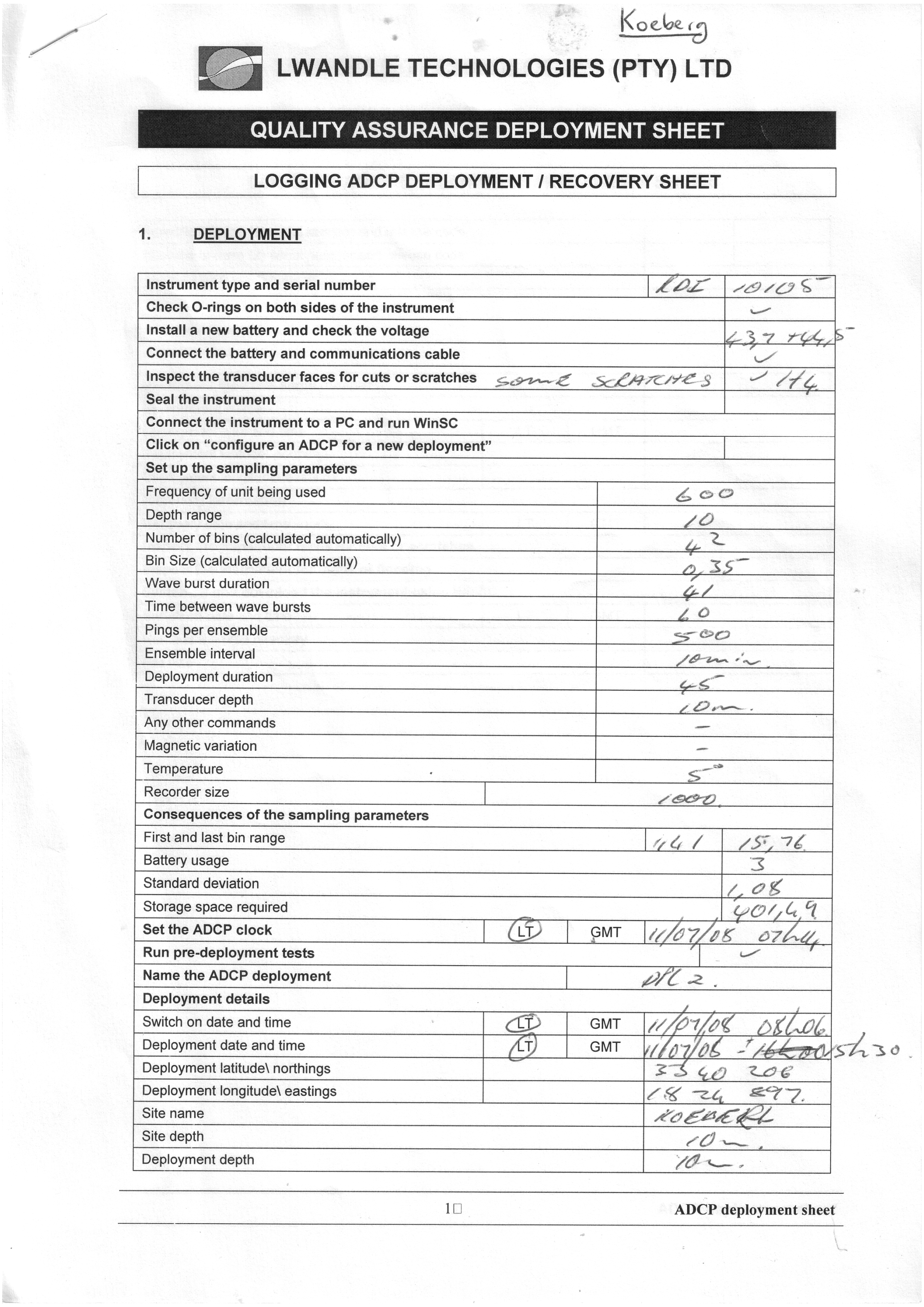
Wave measurements indicated that, over the period of time, the average significant wave height was 2.24m, with a wave period of 12.26s and mean direction to W/WSW.

The temperature values recorded from the various independent instruments are in agreement with each other.

7. INSTRUMENT PARTICULARS FOR SERVICE VISIT ONE

7.1 ADCP RECOVERY AND RE-DEPLOYMENT SHEETS

10m ADCP.



Koeberg

LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

LOGGING ADCP DEPLOYMENT / RECOVERY SHEET

1. DEPLOYMENT

Instrument type and serial number		RDI	10105
Check O-rings on both sides of the instrument			✓
Install a new battery and check the voltage			43,7 +44,5
Connect the battery and communications cable			✓
Inspect the transducer faces for cuts or scratches		SOME SCRATCHES	✓ 1/4
Seal the instrument			
Connect the instrument to a PC and run WinSC			
Click on "configure an ADCP for a new deployment"			
Set up the sampling parameters			
Frequency of unit being used			600
Depth range			10
Number of bins (calculated automatically)			42
Bin Size (calculated automatically)			0,35
Wave burst duration			41
Time between wave bursts			60
Pings per ensemble			500
Ensemble interval			10min.
Deployment duration			45
Transducer depth			10m.
Any other commands			–
Magnetic variation			–
Temperature			5°
Recorder size			1000.
Consequences of the sampling parameters			
First and last bin range		1,41	15,76.
Battery usage			3
Standard deviation			1,08
Storage space required			401,49
Set the ADCP clock	[✓ LT]	GMT	11/07/08 07h44.
Run pre-deployment tests			✓
Name the ADCP deployment			DPL 2.
Deployment details			
Switch on date and time	[✓ LT]	GMT	11/07/08 08h06.
Deployment date and time	[✓ LT]	GMT	11/07/08 - ± ~~16h00~~ 5h30.
Deployment latitude\ northings			33 40 206
Deployment longitude\ eastings			18 24 897.
Site name			KOEBERG
Site depth			10m.
Deployment depth			10m.

1 ADCP deployment sheet

1. RECOVERY Site Name: Koeberg 10m Date: 18 Oct 2008 .

Instrument type and serial number			RDI	10105
Recovery date and time	LT	GMT	**18 Oct 200814h00**	
Latitude **(do not ignore – if same, please indicate)**			33 40.199	
Longitude **(do not ignore – if same, please indicate)**			18 24.907	
Switch off date and time	LT	GMT	-	
File size			677MB	
Was the data copied to memory card?			Y	N_x

2. **RE-DEPLOYMENT Site Name: Koeberg 10m Date 19 Oct 2008**

Instrument type and serial number (do not ignore – if same, please indicate)	RDI	**11424**
Install a new battery and/or check the voltage		**1 * 44.9**
Frequency of unit being used	**600kHz**	
Depth range	**10m**	
Number of bins (calculated automatically)	**42**	
Bin Size (calculated automatically)	**0.35**	
Wave burst duration	**41**	
Time between wave bursts	**60min**	
Pings per ensemble	**500**	
Ensemble interval	**10min**	
Deployment duration	**14days**	
Transducer depth	**10m**	
Any other commands	**Min TP,RI0**	
Temperature	**5**	
Recorder size	**1 * 1GBytes + 128MBytes**	

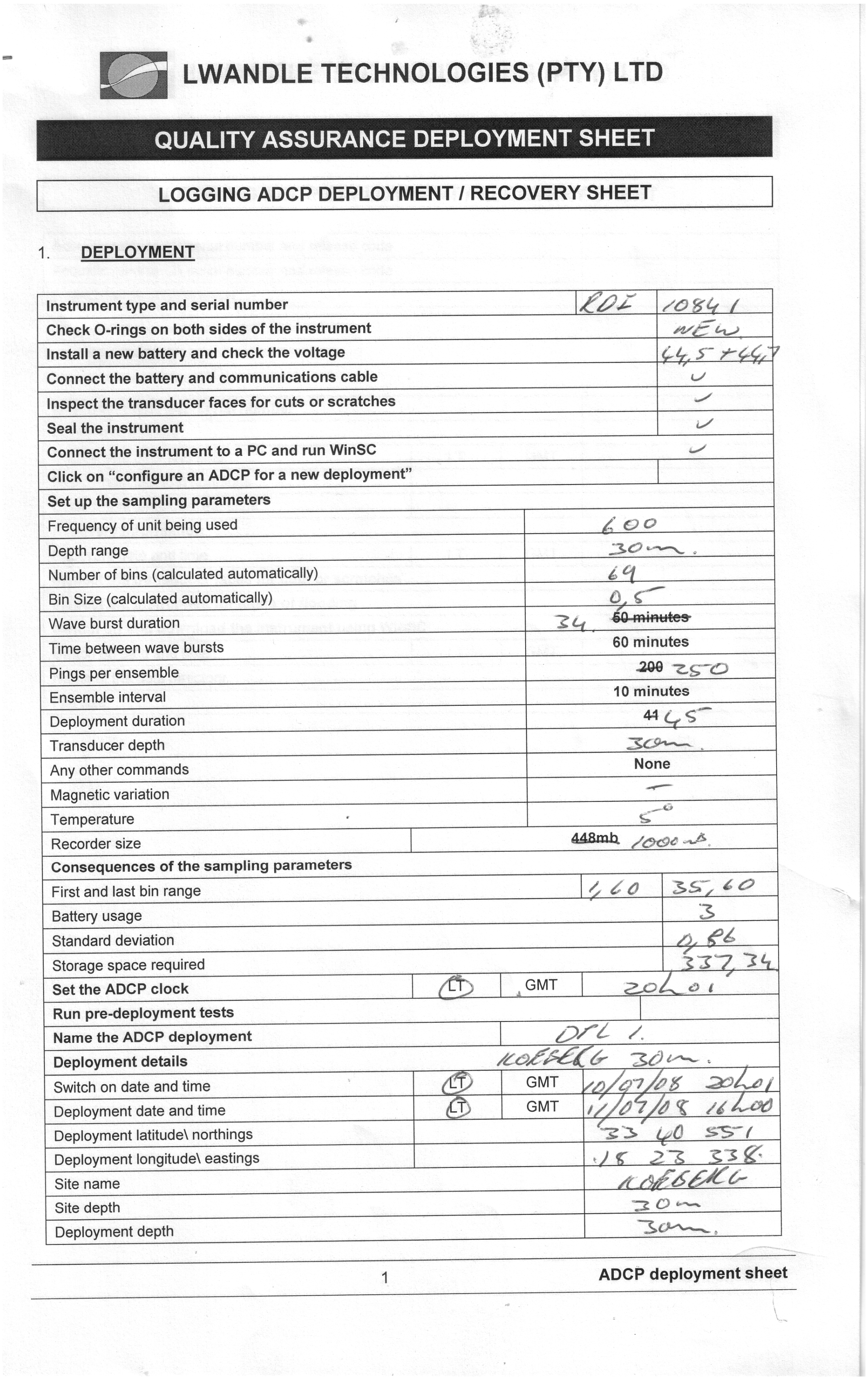
Consequences of the sampling parameters

First and last bin range		**1.41**	**15.76**
Battery usage			**1**
Standard deviation			**1.08**
Storage space required			**129MB**
Set the ADCP clock	LT-x	GMT	**05H13**
Run pre-deployment tests			
Name the ADCP deployment			**K1910**

Deployment details

Switch on date and time	LT-x	GMT	**19 Oct 2008 05h13**	
Deployment date and time	LT-x	GMT	**19 Oct 2008 11h20**	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Site depth	30m	Deployment depth	**10m**	
Acoustic release (1) serial number and release code			**-**	**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**11424_k10m_19102008**	

30m ADCP.



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

LOGGING ADCP DEPLOYMENT / RECOVERY SHEET

1. DEPLOYMENT

Instrument type and serial number	RDI	10841
Check O-rings on both sides of the instrument		NEW.
Install a new battery and check the voltage		44,5 + 44,7
Connect the battery and communications cable		✓
Inspect the transducer faces for cuts or scratches		✓
Seal the instrument		✓
Connect the instrument to a PC and run WinSC		✓
Click on "configure an ADCP for a new deployment"		
Set up the sampling parameters		
Frequency of unit being used		600
Depth range		30m.
Number of bins (calculated automatically)		69
Bin Size (calculated automatically)		0,5
Wave burst duration	34.	~~50 minutes~~
Time between wave bursts		60 minutes
Pings per ensemble		~~200~~ 250
Ensemble interval		10 minutes
Deployment duration		~~41~~ 45
Transducer depth		30m.
Any other commands		None
Magnetic variation		–
Temperature		5°
Recorder size		~~448mb~~ 1000mb.
Consequences of the sampling parameters		
First and last bin range	1,60	35,60
Battery usage		3
Standard deviation		0,86
Storage space required		337,34
Set the ADCP clock	[✓ LT] GMT	20h01
Run pre-deployment tests		
Name the ADCP deployment		DPL 1.
Deployment details		KOEBERG 30m.
Switch on date and time	[✓ LT] GMT	10/07/08 20h01
Deployment date and time	[✓ LT] GMT	11/07/08 16h00
Deployment latitude\ northings		33 40 551
Deployment longitude\ eastings		18 23 338.
Site name		KOEBERG
Site depth		30m
Deployment depth		30m.

1 ADCP deployment sheet

1. RECOVERY Site Name:___ Date:_ .

Instrument type and serial number				10119
Recovery date and time	LT	GMT	**21 Sept 2008 13h00**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**	
Switch off date and time	LT	GMT		
File size				
Was the data copied to memory card?			Y	N

2. RE-DEPLOYMENT Site Name: Koeberg 30m Date 18 Oct 2008

Instrument type and serial number (do not ignore – if same, please indicate)			RDI	**10119**
Install a new battery and/or check the voltage				**1 * 44.9**
Frequency of unit being used			**600kHz**	
Depth range			**30m**	
Number of bins (calculated automatically)			**69**	
Bin Size (calculated automatically)			**0.5**	
Wave burst duration			**34**	
Time between wave bursts			**60min**	
Pings per ensemble			**250**	
Ensemble interval			**10min**	
Deployment duration			**14days**	
Transducer depth			**30m**	
Any other commands			**Min TP,RI0**	
Temperature			**5**	
Recorder size			**2 * 1GBytes**	

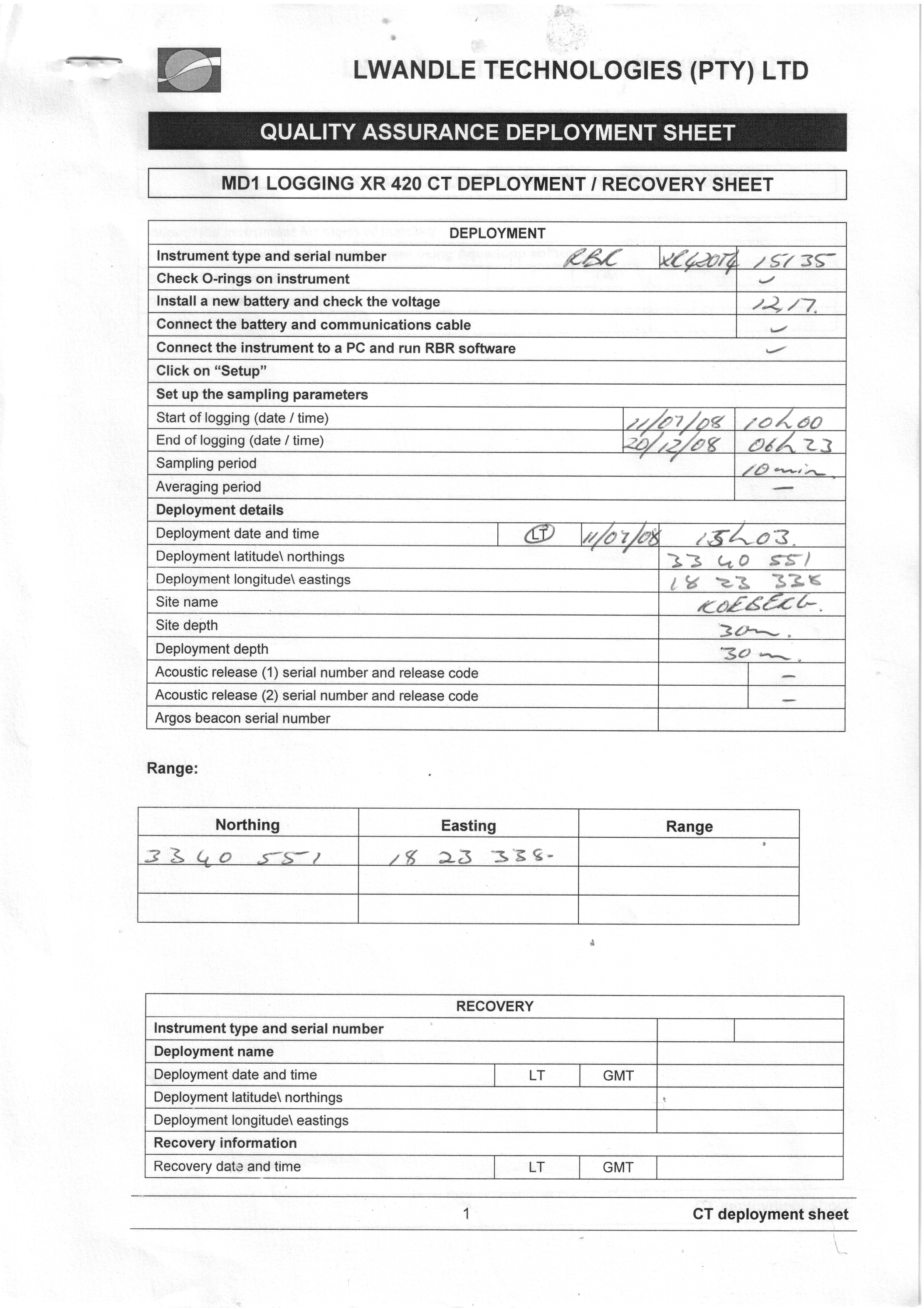
Consequences of the sampling parameters

First and last bin range			**1.6**	**35.6**
Battery usage				**1**
Standard deviation				**0.86**
Storage space required				**112.5**
Set the ADCP clock	LT-x	GMT	**04h00**	
Run pre-deployment tests				
Name the ADCP deployment			**K3010**	

Deployment details

Switch on date and time	LT-x	GMT	**18 Oct 2008 04h00**	
Deployment date and time	LT-x	GMT	**18 Oct 2008 12:35**	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**	
Site depth	30m	Deployment depth		**30m**
Acoustic release (1) serial number and release code			**Cart**	**32383**
Acoustic release (2) serial number and release code				
Argos beacon serial number				
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**10119_K30m_18102008**	

7.2 RBR-CT LOGGERS RECOVERY AND RE-DEPLOYMENT SHEETS



LWANDLE TECHNOLOGIES (PTY) LTD

QUALITY ASSURANCE DEPLOYMENT SHEET

MD1 LOGGING XR 420 CT DEPLOYMENT / RECOVERY SHEET

DEPLOYMENT			
Instrument type and serial number	RBC	XR420T4	15135
Check O-rings on instrument			✓
Install a new battery and check the voltage			12,17.
Connect the battery and communications cable			✓
Connect the instrument to a PC and run RBR software			✓
Click on "Setup"			
Set up the sampling parameters			
Start of logging (date / time)		11/07/08	10h00
End of logging (date / time)		20/12/08	06h23
Sampling period			10 min.
Averaging period			—
Deployment details			
Deployment date and time	(LT)	11/07/08	15h03.
Deployment latitude\ northings			33 40 551
Deployment longitude\ eastings			18 23 338
Site name			KOEBERG.
Site depth			30m.
Deployment depth			30 m.
Acoustic release (1) serial number and release code			—
Acoustic release (2) serial number and release code			—
Argos beacon serial number			

Range:

Northing	Easting	Range
33 40 551	18 23 338-	

RECOVERY			
Instrument type and serial number			
Deployment name			
Deployment date and time	LT	GMT	
Deployment latitude\ northings			
Deployment longitude\ eastings			
Recovery information			
Recovery date and time	LT	GMT	

1 **CT deployment sheet**

1. <u>RECOVERY</u> Site Name: <u>Koeberg thermister string</u> Date: <u>21 Sept 2008.</u>

Instrument type and serial number			RBR	015135
Recovery date and time	LT	GMT	<u>21 Sept 2008 13h10</u>	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LT	GMT	22 Sept 2008 09h28	
File size				
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			015135_21092008_1310	

2. <u>RE-DEPLOYMENT</u> Site Name: <u>Koeberg 10m</u> Date: 19 Oct 2008

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12995
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	19 Oct 2008	05h33:40
End of logging (date / time)	27 Nov 2008	12h00
Memory usage		.4%
Battery usage		978mAH

Deployment details

Deployment date and time	LT	GMT	19 Oct 2008 11:20	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Site name			Koeberg 10m	
Site depth			10m	
Deployment depth			10m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			**12995_19102008**	

3. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 18 Oct 2008

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12997
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	18 Oct 2008	04h40
End of logging (date / time)	27 Nov 2008	04h31
Memory usage		.4%
Battery usage		997mAH

Deployment details

Deployment date and time	LT - x	GMT	18 Oct 2008 12:35
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.397**
Site name			Koeberg 30m
Site depth			30m
Deployment depth			30m
Acoustic release (1) serial number and release code			**-**
Acoustic release (2) serial number and release code			**-**
Argos beacon serial number			**-**
Save *log* file (filename format: ***serialnumber_date***)			**12997_19102008**

7.3 ADCP CONFIGURATION FILES

10m ADCP.

```
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 336.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1128
;Saved Screen        = 3
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 124.91 MB (130974144 bytes)
;Power usage         = 410.91 Wh
;Battery usage       = 0.9
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
```

```
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

30m ADCP.

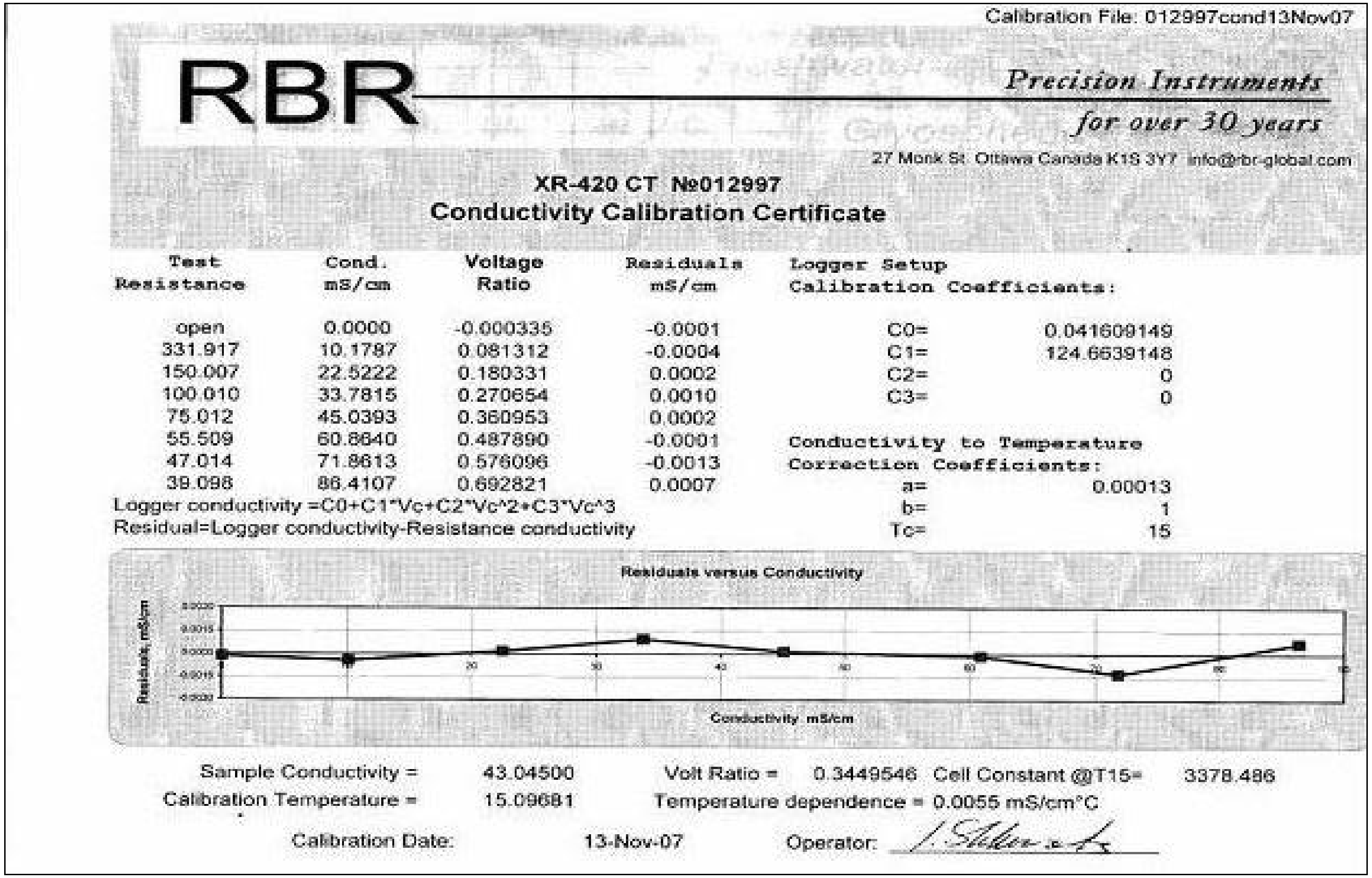
```
CR1
CF11101
EA0
EB0
ED100
ES35
RI0
EX11111
EZ1111111
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:01.00
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 1080.00
;Battery packs       = 3
;Automatic TP        = YES
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 401.49 MB (420988320 bytes)
```

```
;Power usage         = 1320.77 Wh
;Battery usage       = 2.9
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.


CR1
CF11101
EA0
EB0
ED300
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN69
WP250
WS50
WV175
HD111000000
HB5
HP4080
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 360.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 2000
;Saved Screen        = 2
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.60 m
;Last cell range     = 35.60 m
```

```
;Max range          = 38.22 m
;Standard deviation = 0.86 cm/s
;Ensemble size      = 1534 bytes
;Storage required   = 112.45 MB (117908640 bytes)
;Power usage        = 447.68 Wh
;Battery usage      = 1.0
;Samples / Wv Burst = 4080
;Min NonDir Wave Per= 2.59 s
;Min Dir Wave Period= 4.31 s
;Bytes / Wave Burst = 318320
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

7.4 RBR-CT CALIBRATION CERTIFICATES



Calibration File: 012997cond13Nov07

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012997
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000335	-0.0001
331.917	10.1787	0.081312	-0.0004
150.007	22.5222	0.180331	0.0002
100.010	33.7815	0.270654	0.0010
75.012	45.0393	0.360953	0.0002
55.509	60.8640	0.487890	-0.0001
47.014	71.8613	0.576096	-0.0013
39.098	86.4107	0.692821	0.0007

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.041609149
C1= 124.6639148
C2= 0
C3= 0

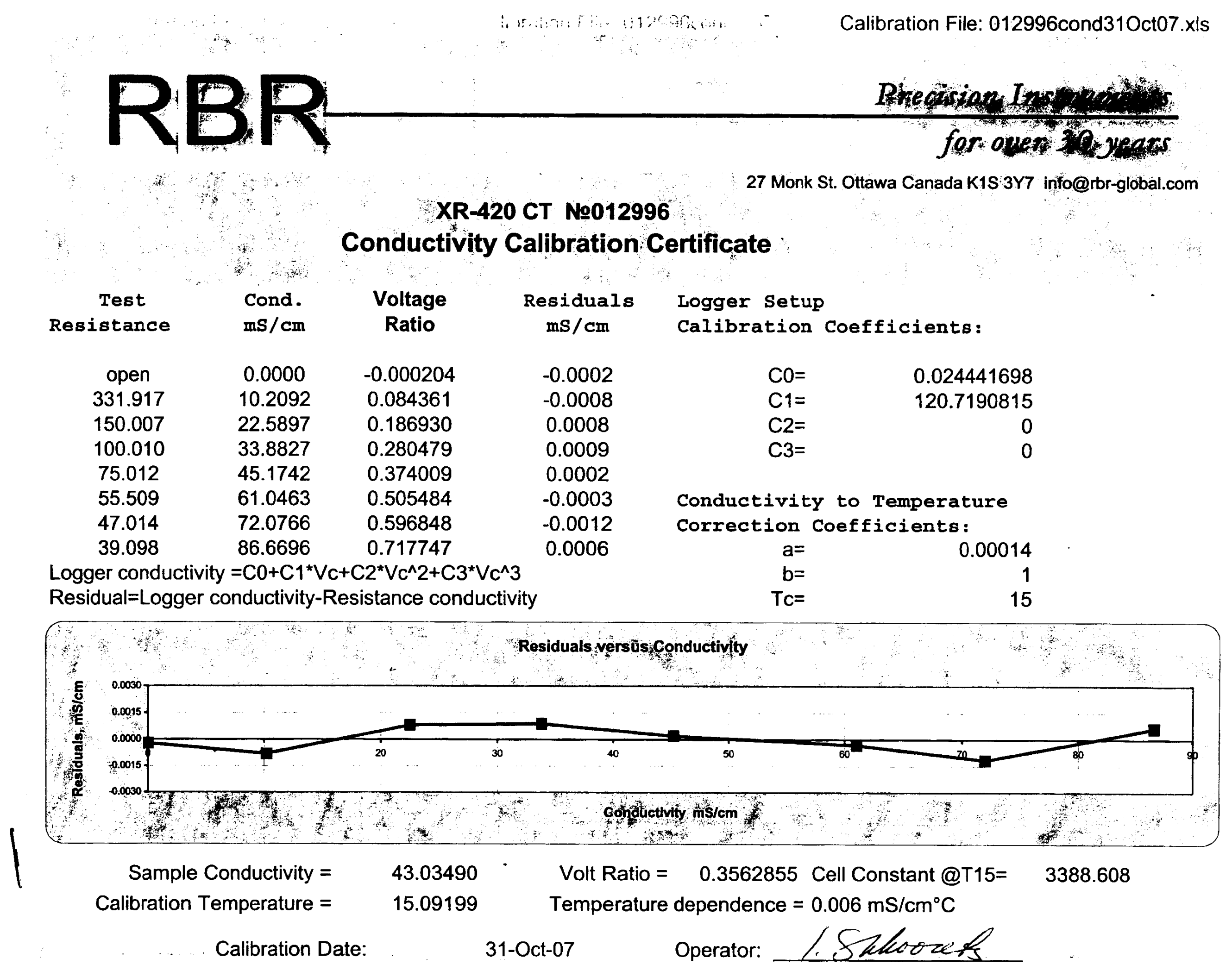
Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 43.04500
Calibration Temperature = 15.09681
Volt Ratio = 0.3449546
Cell Constant @T15= 3378.486
Temperature dependence = 0.0055 mS/cm°C

Calibration Date: 13-Nov-07
Operator: J. Stellen



Calibration File: 012996cond31Oct07.xls

RBR

Precision Instruments for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012996
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000204	-0.0002
331.917	10.2092	0.084361	-0.0008
150.007	22.5897	0.186930	0.0008
100.010	33.8827	0.280479	0.0009
75.012	45.1742	0.374009	0.0002
55.509	61.0463	0.505484	-0.0003
47.014	72.0766	0.596848	-0.0012
39.098	86.6696	0.717747	0.0006

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.024441698
C1= 120.7190815
C2= 0
C3= 0

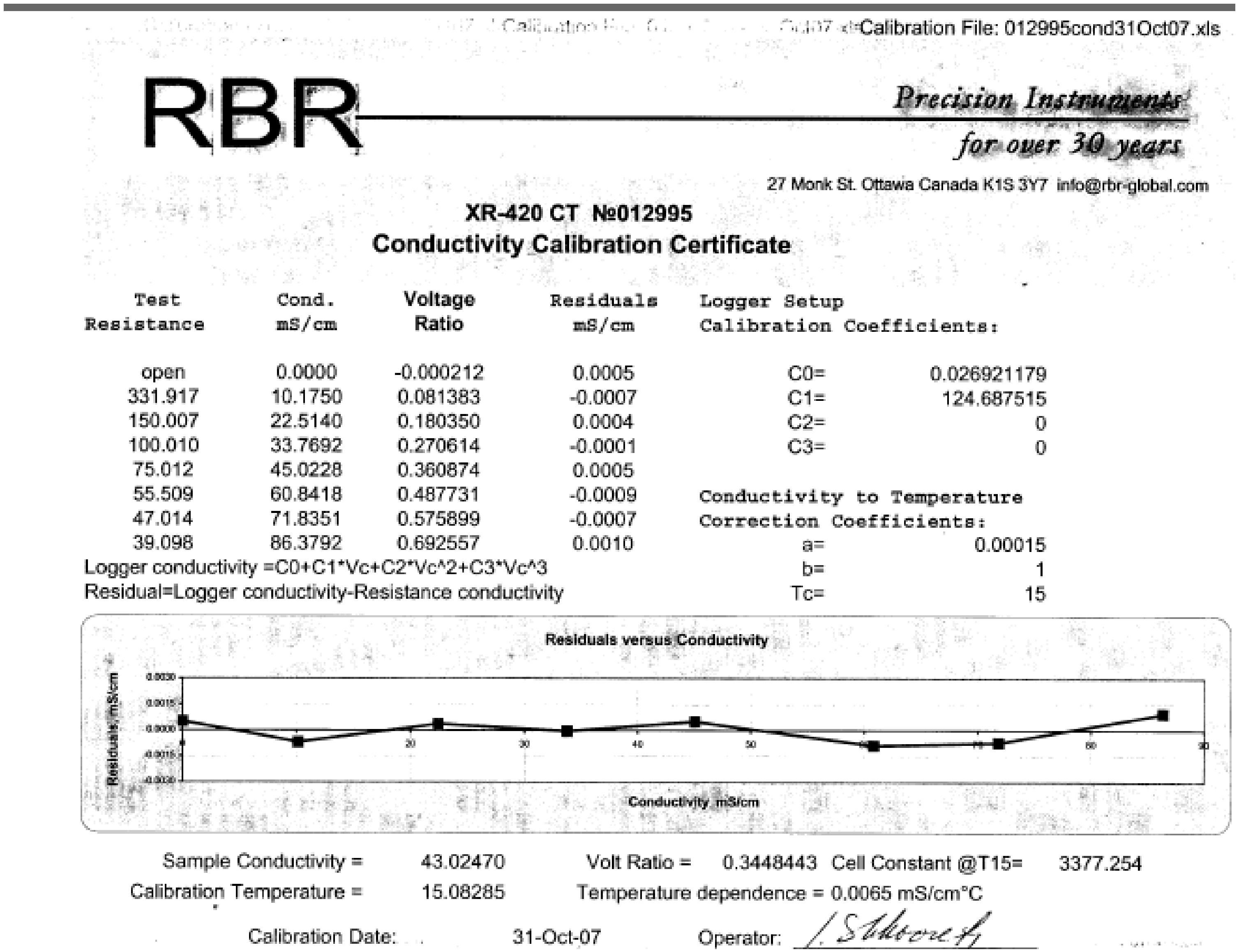
Conductivity to Temperature
Correction Coefficients:

a= 0.00014
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 43.03490 Volt Ratio = 0.3562855 Cell Constant @T15= 3388.608
Calibration Temperature = 15.09199 Temperature dependence = 0.006 mS/cm°C

Calibration Date: 31-Oct-07 Operator:



Calibration File: 012995cond31Oct07.xls

RBR *Precision Instruments for over 30 years*

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012995

Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000212	0.0005
331.917	10.1750	0.081383	-0.0007
150.007	22.5140	0.180350	0.0004
100.010	33.7692	0.270614	-0.0001
75.012	45.0228	0.360874	0.0005
55.509	60.8418	0.487731	-0.0009
47.014	71.8351	0.575899	-0.0007
39.098	86.3792	0.692557	0.0010

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3

Residual=Logger conductivity-Resistance conductivity

Logger Setup

Calibration Coefficients:

C0=	0.026921179
C1=	124.687515
C2=	0
C3=	0

Conductivity to Temperature

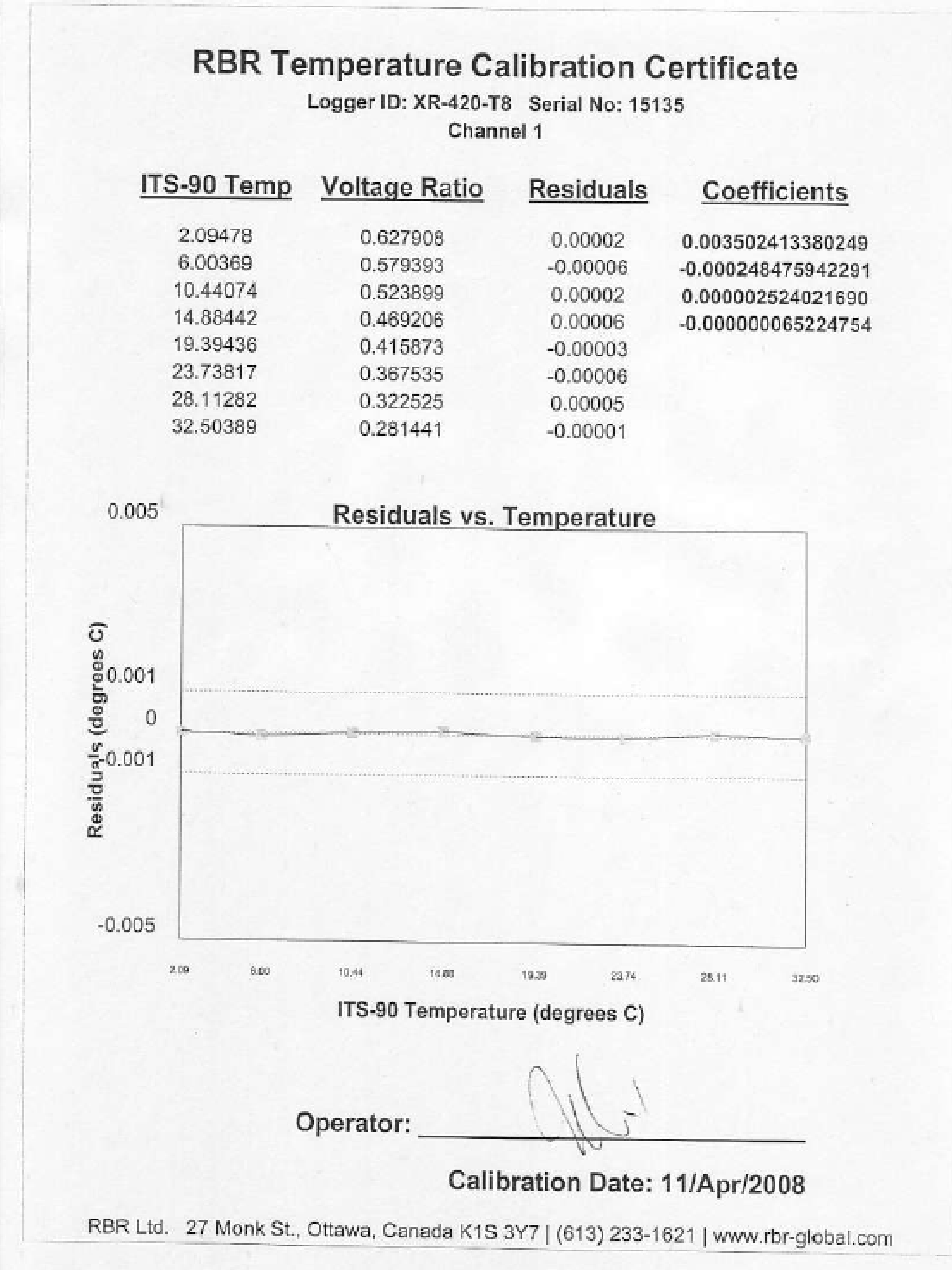
Correction Coefficients:

a=	0.00015
b=	1
Tc=	15

Sample Conductivity = 43.02470 Volt Ratio = 0.3448443 Cell Constant @T15= 3377.254

Calibration Temperature = 15.08285 Temperature dependence = 0.0065 mS/cm°C

Calibration Date: 31-Oct-07 Operator:



RBR Temperature Calibration Certificate

Logger ID: XR-420-T8 Serial No: 15135

Channel 1

ITS-90 Temp	Voltage Ratio	Residuals	Coefficients
2.09478	0.627908	0.00002	0.003502413380249
6.00369	0.579393	-0.00006	-0.000248475942291
10.44074	0.523899	0.00002	0.000002524021690
14.88442	0.469206	0.00006	-0.000000065224754
19.39436	0.415873	-0.00003	
23.73817	0.367535	-0.00006	
28.11282	0.322525	0.00005	
32.50389	0.281441	-0.00001	

Residuals vs. Temperature

Residuals (degrees C)

0.005

0.001

0

-0.001

-0.005

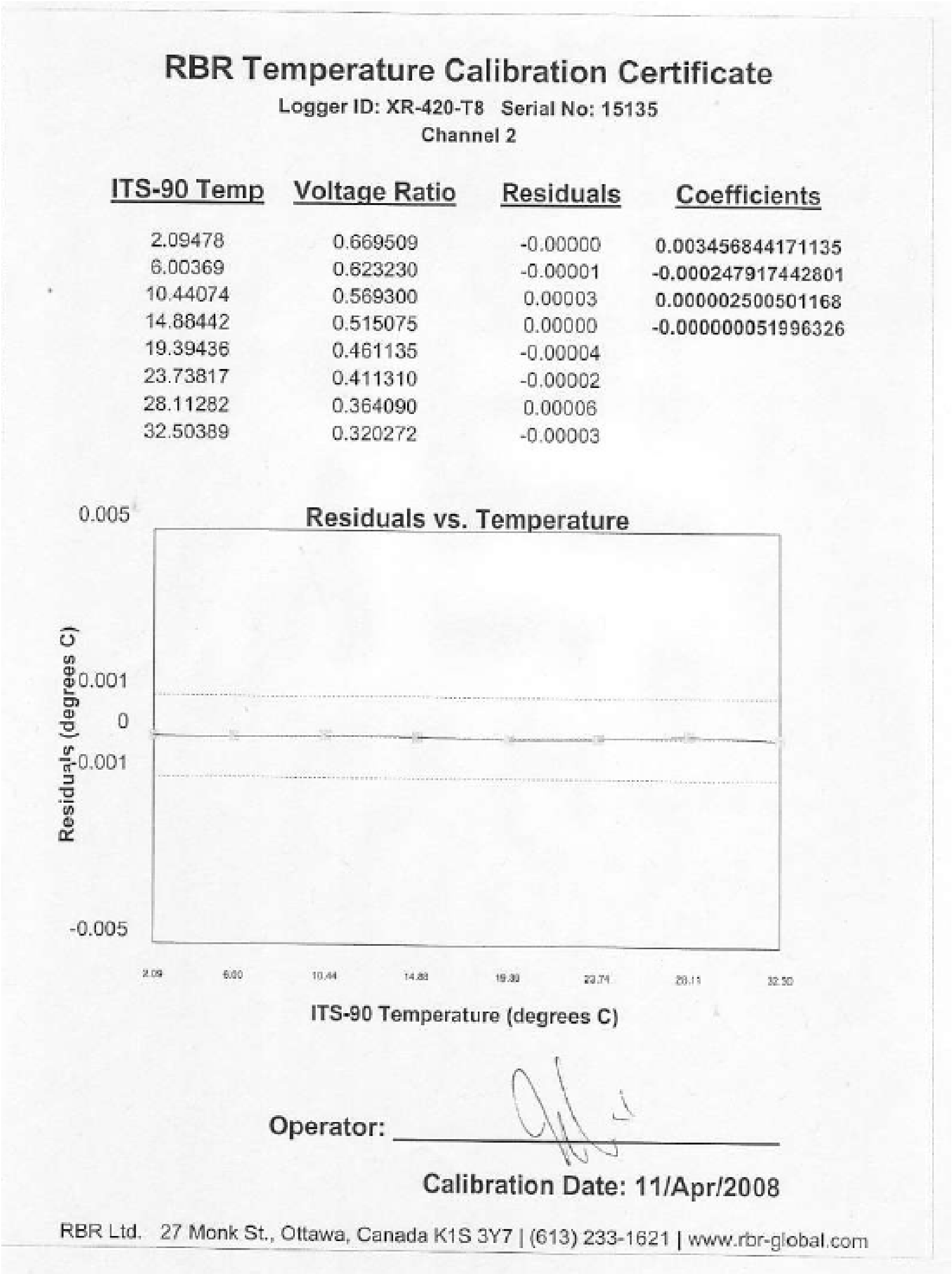
2.09 6.00 10.44 14.88 19.39 23.74 28.11 32.50

ITS-90 Temperature (degrees C)

Operator:

Calibration Date: 11/Apr/2008

RBR Ltd. 27 Monk St., Ottawa, Canada K1S 3Y7 | (613) 233-1621 | www.rbr-global.com



RBR Temperature Calibration Certificate

Logger ID: XR-420-T8 Serial No: 15135

Channel 2

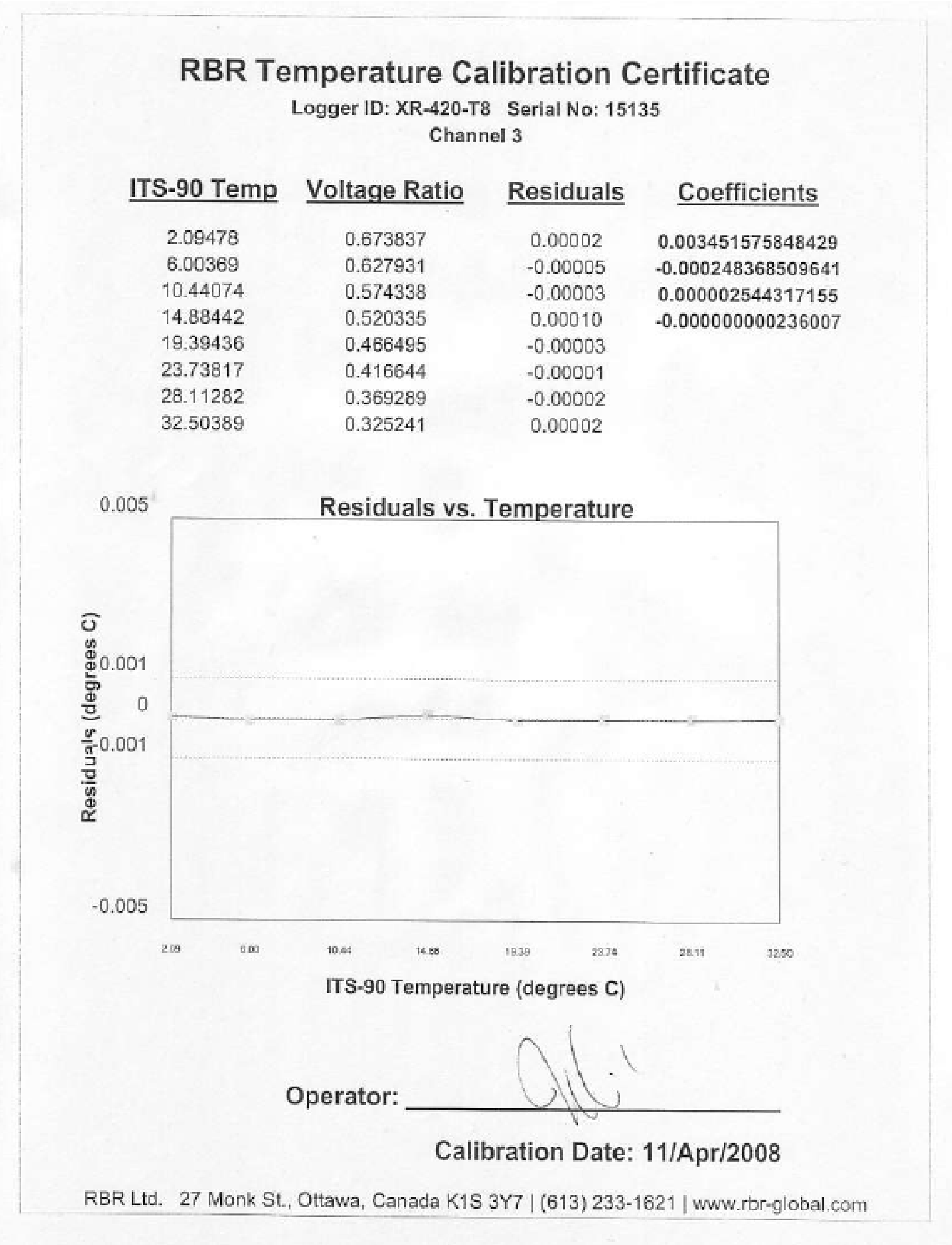
ITS-90 Temp	Voltage Ratio	Residuals	Coefficients
2.09478	0.669509	-0.00000	0.003456844171135
6.00369	0.623230	-0.00001	-0.000247917442801
10.44074	0.569300	0.00003	0.000002500501168
14.88442	0.515075	0.00000	-0.000000051996326
19.39436	0.461135	-0.00004	
23.73817	0.411310	-0.00002	
28.11282	0.364090	0.00006	
32.50389	0.320272	-0.00003	

Residuals vs. Temperature

Operator: ____________

Calibration Date: 11/Apr/2008

RBR Ltd. 27 Monk St., Ottawa, Canada K1S 3Y7 | (613) 233-1621 | www.rbr-global.com



RBR Temperature Calibration Certificate

Logger ID: XR-420-T8 Serial No: 15135
Channel 3

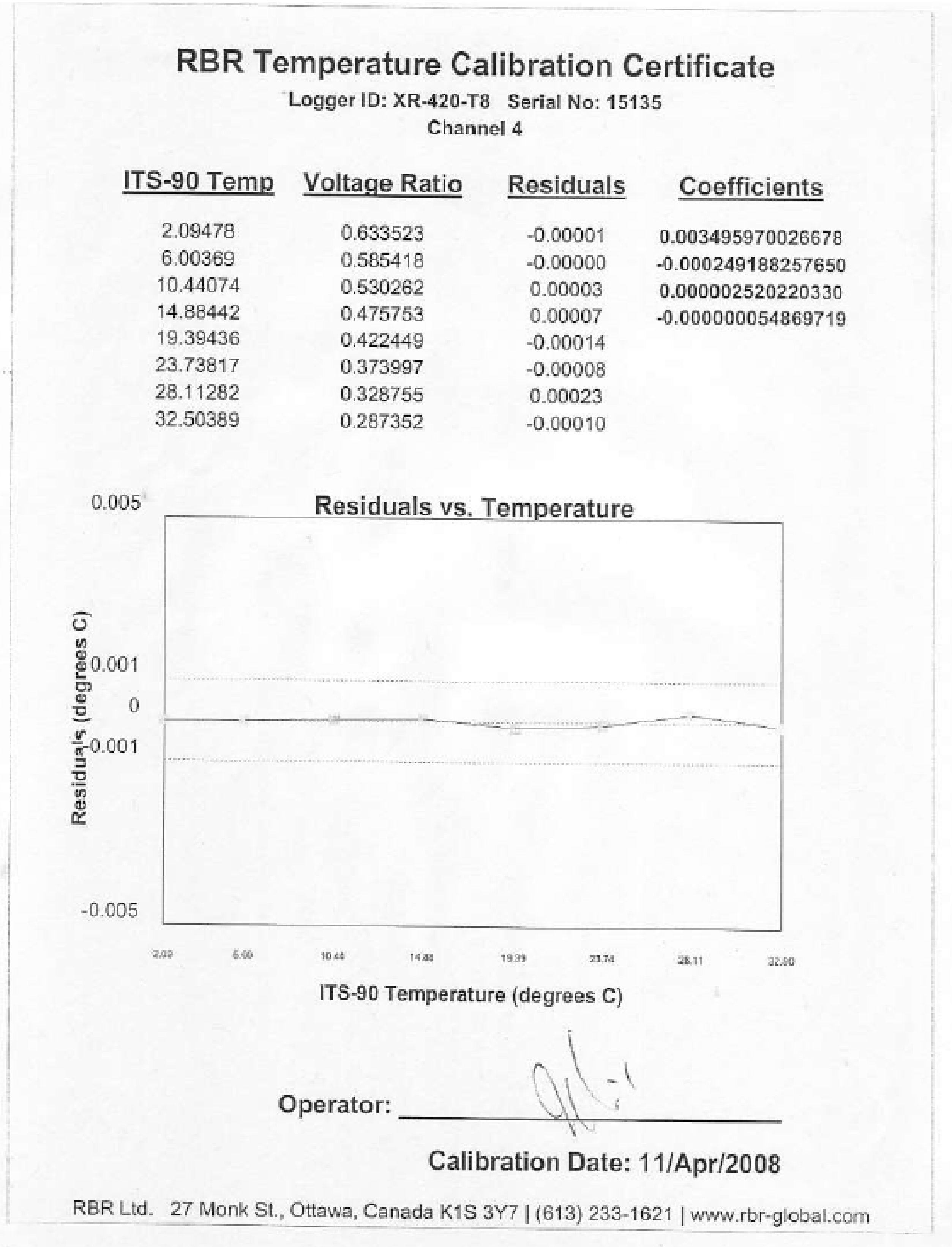
ITS-90 Temp	Voltage Ratio	Residuals	Coefficients
2.09478	0.673837	0.00002	0.003451575848429
6.00369	0.627931	-0.00005	-0.000248368509641
10.44074	0.574338	-0.00003	0.000002544317155
14.88442	0.520335	0.00010	-0.000000000236007
19.39436	0.466495	-0.00003	
23.73817	0.416644	-0.00001	
28.11282	0.369289	-0.00002	
32.50389	0.325241	0.00002	

Residuals vs. Temperature

Operator: ____________________

Calibration Date: 11/Apr/2008

RBR Ltd. 27 Monk St., Ottawa, Canada K1S 3Y7 | (613) 233-1621 | www.rbr-global.com



RBR Temperature Calibration Certificate

Logger ID: XR-420-T8 Serial No: 15135
Channel 4

ITS-90 Temp	Voltage Ratio	Residuals	Coefficients
2.09478	0.633523	-0.00001	0.003495970026678
6.00369	0.585418	-0.00000	-0.000249188257650
10.44074	0.530262	0.00003	0.000002520220330
14.88442	0.475753	0.00007	-0.000000054869719
19.39436	0.422449	-0.00014	
23.73817	0.373997	-0.00008	
28.11282	0.328755	0.00023	
32.50389	0.287352	-0.00010	

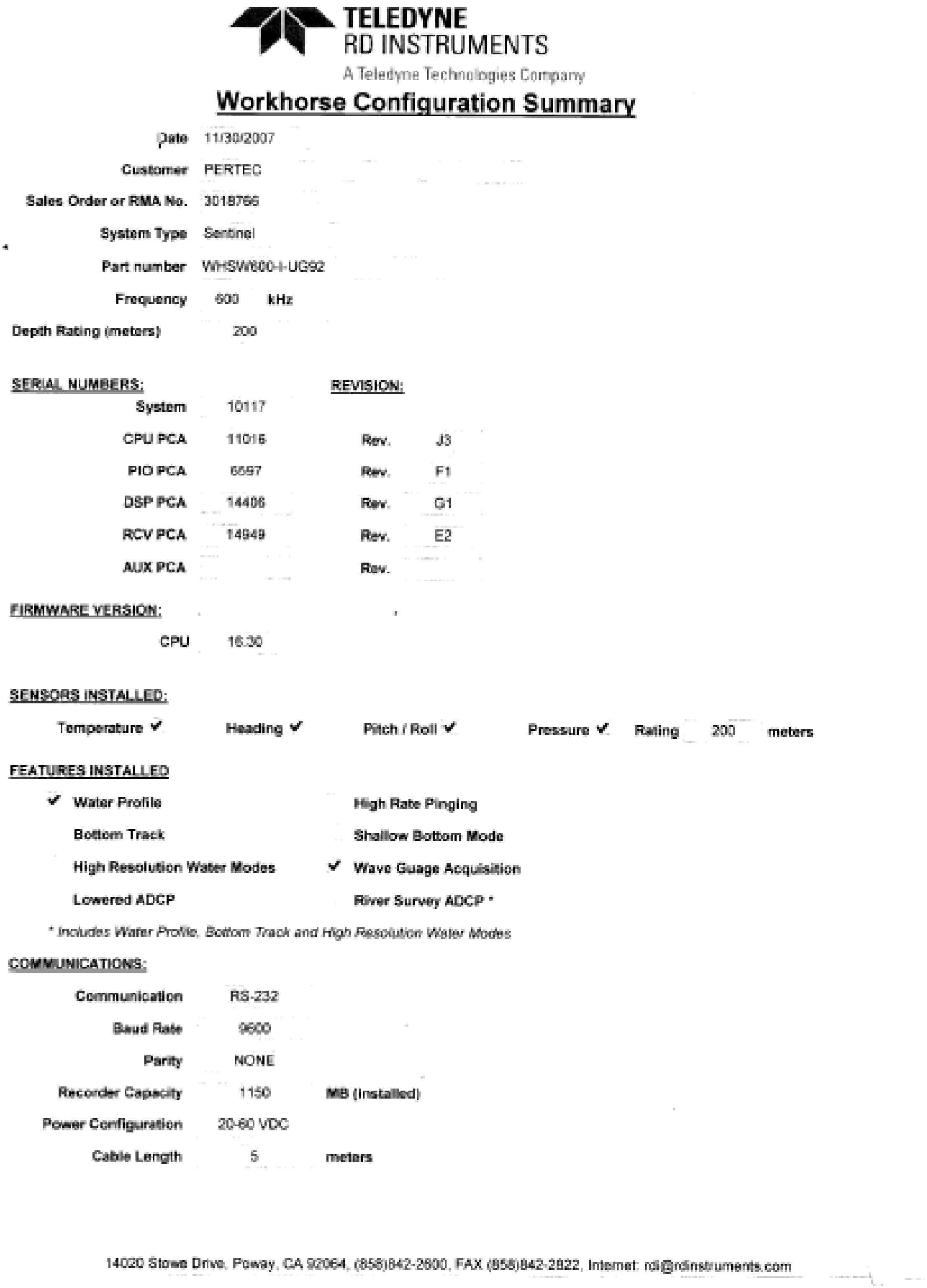
Residuals vs. Temperature

Operator: ____________________

Calibration Date: 11/Apr/2008

RBR Ltd. 27 Monk St., Ottawa, Canada K1S 3Y7 | (613) 233-1621 | www.rbr-global.com

7.5 TRDI ADCP CALIBRATION CERTIFICATE



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 11/30/2007
Customer PERTEC
Sales Order or RMA No. 3018766
System Type Sentinel
Part number WHSW600-I-UG92
Frequency 600 kHz
Depth Rating (meters) 200

SERIAL NUMBERS:		REVISION:	
System	10117		
CPU PCA	11016	Rev.	J3
PIO PCA	6597	Rev.	F1
DSP PCA	14406	Rev.	G1
RCV PCA	14949	Rev.	E2
AUX PCA		Rev.	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ Heading ✓ Pitch / Roll ✓ Pressure ✓ Rating 200 meters

FEATURES INSTALLED

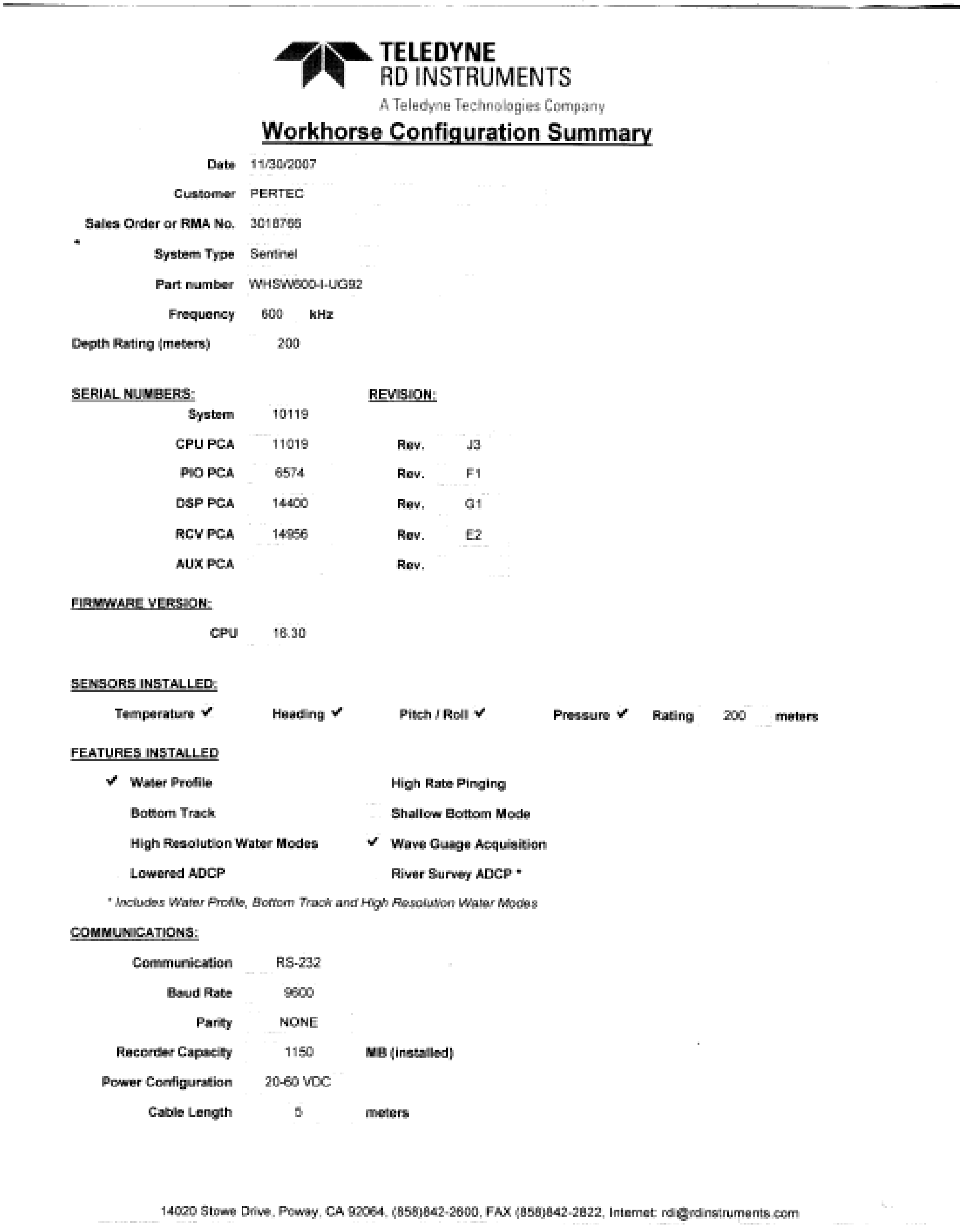
- ✓ Water Profile
- Bottom Track
- High Resolution Water Modes
- Lowered ADCP
- High Rate Pinging
- Shallow Bottom Mode
- ✓ Wave Guage Acquisition
- River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232
Baud Rate 9600
Parity NONE
Recorder Capacity 1150 MB (installed)
Power Configuration 20-60 VDC
Cable Length 5 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 11/30/2007

Customer PERTEC

Sales Order or RMA No. 3018766

System Type Sentinel

Part number WHSW600-I-UG92

Frequency 600 **kHz**

Depth Rating (meters) 200

SERIAL NUMBERS:		**REVISION:**	
System	10119		
CPU PCA	11019	**Rev.**	J3
PIO PCA	6574	**Rev.**	F1
DSP PCA	14400	**Rev.**	G1
RCV PCA	14956	**Rev.**	E2
AUX PCA		**Rev.**	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ **Heading** ✓ **Pitch / Roll** ✓ **Pressure** ✓ **Rating** 200 **meters**

FEATURES INSTALLED

✓ **Water Profile**
Bottom Track
High Resolution Water Modes
Lowered ADCP
High Rate Pinging
Shallow Bottom Mode
✓ **Wave Guage Acquisition**
River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232

Baud Rate 9600

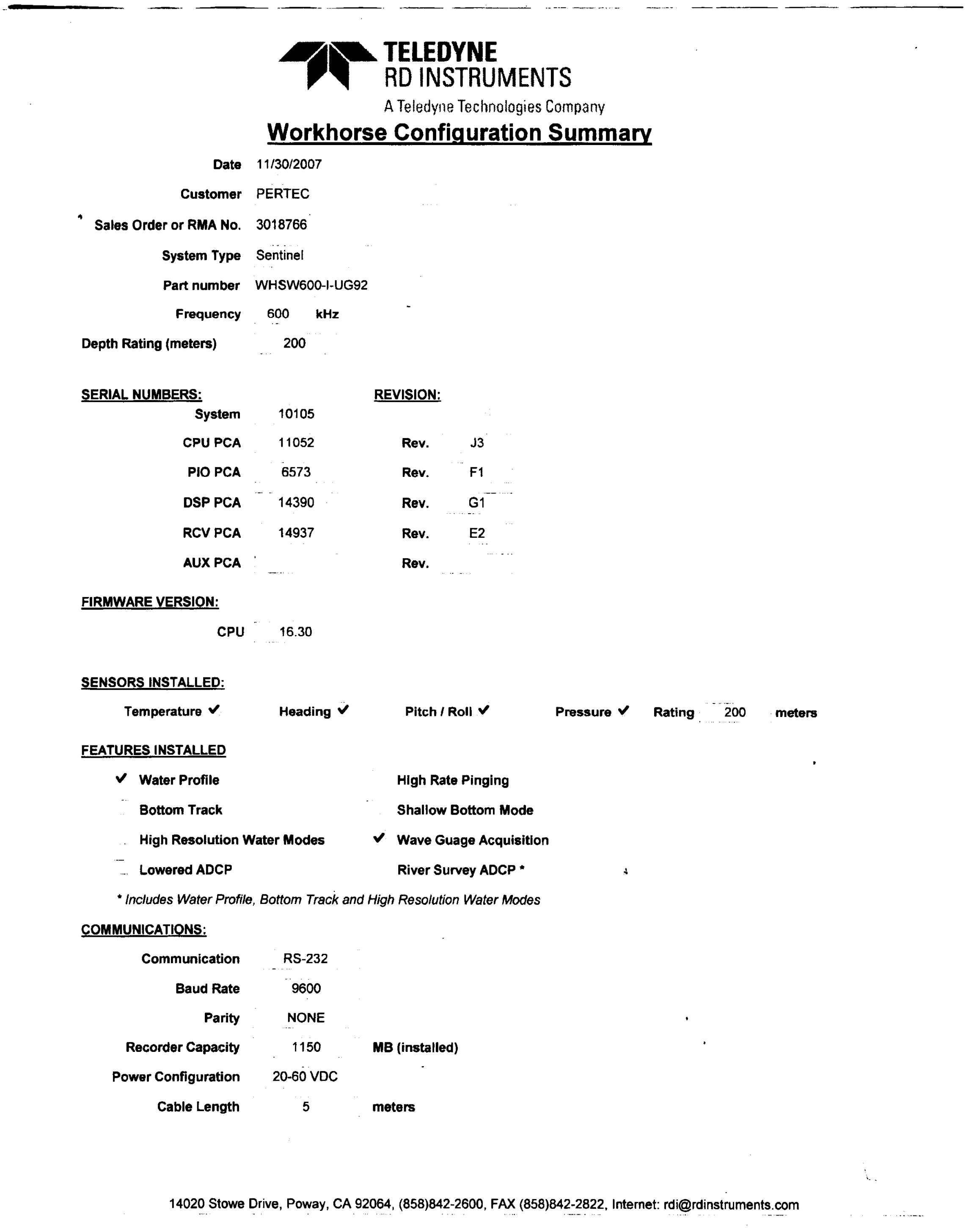
Parity NONE

Recorder Capacity 1150 **MB (installed)**

Power Configuration 20-60 VDC

Cable Length 5 **meters**

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 11/30/2007

Customer PERTEC

Sales Order or RMA No. 3018766

System Type Sentinel

Part number WHSW600-I-UG92

Frequency 600 **kHz**

Depth Rating (meters) 200

SERIAL NUMBERS:		**REVISION:**	
System	10105		
CPU PCA	11052	**Rev.**	J3
PIO PCA	6573	**Rev.**	F1
DSP PCA	14390	**Rev.**	G1
RCV PCA	14937	**Rev.**	E2
AUX PCA		**Rev.**	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ **Heading** ✓ **Pitch / Roll** ✓ **Pressure** ✓ **Rating** 200 **meters**

FEATURES INSTALLED

✓	**Water Profile**		**High Rate Pinging**
	Bottom Track		**Shallow Bottom Mode**
	High Resolution Water Modes	✓	**Wave Guage Acquisition**
	Lowered ADCP		**River Survey ADCP ***

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232

Baud Rate 9600

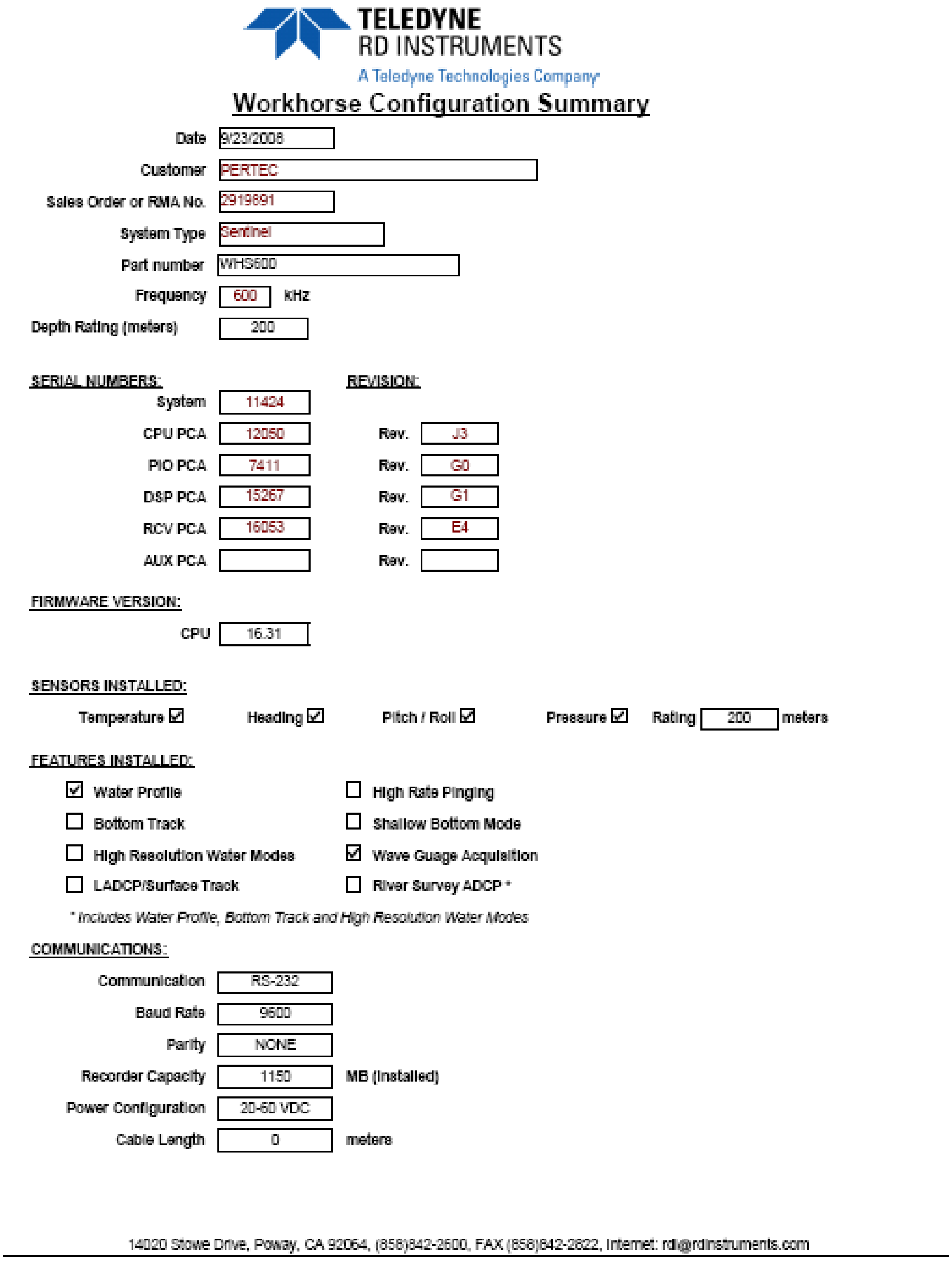
Parity NONE

Recorder Capacity 1150 **MB (installed)**

Power Configuration 20-60 VDC

Cable Length 5 **meters**

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 9/23/2008
Customer PERTEC
Sales Order or RMA No. 2919691
System Type Sentinel
Part number WHS600
Frequency 600 kHz
Depth Rating (meters) 200

SERIAL NUMBERS: **REVISION:**

System	11424		
CPU PCA	12050	Rev.	J3
PIO PCA	7411	Rev.	G0
DSP PCA	15267	Rev.	G1
RCV PCA	16053	Rev.	E4
AUX PCA		Rev.	

FIRMWARE VERSION:

CPU 16.31

SENSORS INSTALLED:

Temperature ☑ Heading ☑ Pitch / Roll ☑ Pressure ☑ Rating 200 meters

FEATURES INSTALLED:

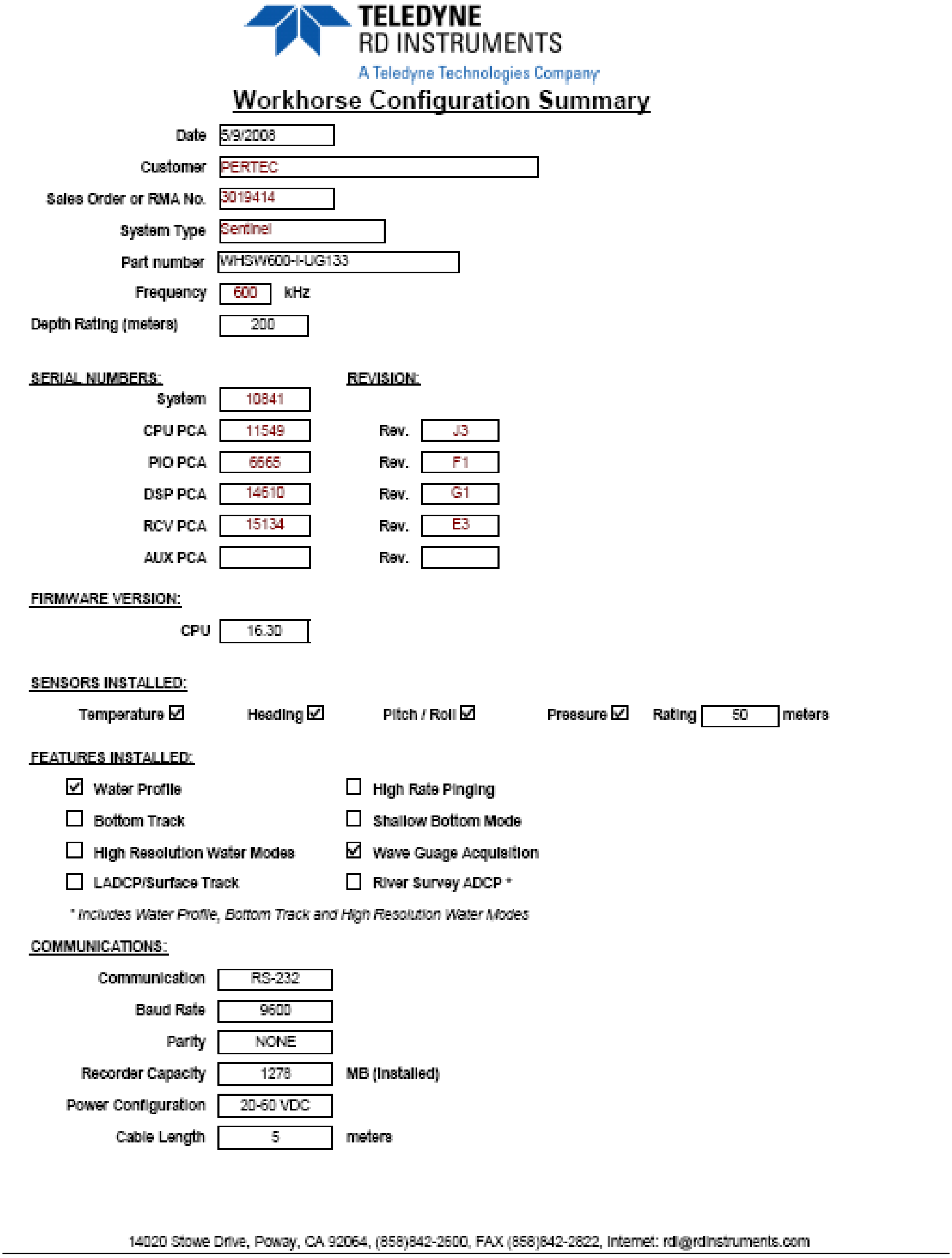
☑ Water Profile
☐ Bottom Track
☐ High Resolution Water Modes
☐ LADCP/Surface Track
☐ High Rate Pinging
☐ Shallow Bottom Mode
☑ Wave Guage Acquisition
☐ River Survey ADCP *

* *Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232
Baud Rate 9600
Parity NONE
Recorder Capacity 1150 MB (installed)
Power Configuration 20-60 VDC
Cable Length 0 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2622, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 5/9/2008
Customer PERTEC
Sales Order or RMA No. 3019414
System Type Sentinel
Part number WHSW600-I-UG133
Frequency 600 kHz
Depth Rating (meters) 200

SERIAL NUMBERS:		REVISION:	
System	10841		
CPU PCA	11549	Rev.	J3
PIO PCA	6665	Rev.	F1
DSP PCA	14610	Rev.	G1
RCV PCA	15134	Rev.	E3
AUX PCA		Rev.	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ☑ Heading ☑ Pitch / Roll ☑ Pressure ☑ Rating 50 meters

FEATURES INSTALLED:

☑ Water Profile
☐ Bottom Track
☐ High Resolution Water Modes
☐ LADCP/Surface Track
☐ High Rate Pinging
☐ Shallow Bottom Mode
☑ Wave Guage Acquisition
☐ River Survey ADCP *

* Includes Water Profile, Bottom Track and High Resolution Water Modes

COMMUNICATIONS:

Communication RS-232
Baud Rate 9600
Parity NONE
Recorder Capacity 1278 MB (installed)
Power Configuration 20-60 VDC
Cable Length 5 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com

8. REPORT FROM THE CSIR

CERTIFICATE OF ANALYSIS

Our ref: H:\USERS\MARLAB\REPORTS\Malr2744

Report Number: MALR2744

4 July 2008

Lwandle Technologies
Gabriel Place
1 Gabriel Road
Plumstead
7800

Attention Craig Matthysen

CHEMICAL ANALYSIS: Water samples (Order No.:)
Samples received: 02/07/08
Analysis completed: 04/07/08
Sample description: Seawater in sealed plastic bottles.

Lab No	Sample Id	*Total Suspended Solids in mg/L	*Salinity PSU
33916	**S1**	*<5*	*34.8*
33917	**S2**	*<5*	*34.7*
33918	**S3**	*<5*	*34.8*
33919	**S4**	*<5*	*34.8*
33920	**S5**	*7*	*34.8*
33921	**S6**	*6*	*34.9*
33922	**S7**	*<5*	*34.8*
33923	**S8**	*<5*	*34.7*
33924	**S9**	*<5*	*34.8*
33925	**S10**	*6*	*34.8*
33926	**S11**	*<5*	*34.8*

Andrew Pascall
MARINE ANALYTICAL SERVICES
Laboratory Manager

Sebastian Brown
MARINE ANALYTICAL SERVICES
Deputy Laboratory Manager

- Method not included in the scope of accreditation.

CERTIFICATE OF ANALYSIS

Our ref: H:\USERS\MARLAB\REPORTS\Malr2766

Report Number: MALR2766

24 July 2008

Lwandle Technologies
Gabriel Place
1 Gabriel Road
Plumstead
7800

Attention Craig Matthysen

CHEMICAL ANALYSIS: Water samples (Order No.:)
Samples received: 22/07/08
Analysis completed: 24/07/08
Sample description: Seawater in sealed plastic bottles.

Lab	**Sample**	**Sample**	**Total Suspended Solids**	**EC**	**Salinity**
No	**Id**	**Date**	**in mg/L**	**in S/m**	**PSU**
37085	**Koeberg S1**	**11/07/08**	*2*	*4.1*	*34.2*
37086	**Koeberg S2**	**11/07/08**	*3*	*4.1*	*34.3*
37087	**Koeberg S3**	**11/07/08**	*2*	*4.1*	*34.3*
37088	**Koeberg S4**	**11/07/08**	*3*	*4.0*	*33.7*
37089	**Koeberg S5**	**11/07/08**	*<2*	*4.1*	*34.3*
37090	**Koeberg S6**	**11/07/08**	*<2*	*4.1*	*34.4*
37091	**Koeberg S7**	**11/07/08**	*4*	*4.1*	*34.5*
37092	**Koeberg S8**	**11/07/08**	*<2*	*4.1*	*34.5*
37093	**Koeberg S9**	**11/07/08**	*2*	*4.1*	*34.5*
37094	**Koeberg S10**	**11/07/08**	*2*	*4.1*	*34.5*
37095	**Koeberg S11**	**11/07/08**	*16*	*4.1*	*34.6*

Andrew Pascall	Sebastian Brown
MARINE ANALYTICAL SERVICES	MARINE ANALYTICAL SERVICES
Laboratory Manager	Deputy Laboratory Manager

- Method not included in the scope of accreditation.

AMENDED CERTIFICATE OF ANALYSIS

Our ref: H:\USERS\MARLAB\REPORTS\Malr2852A

Report Number: MALR2852A

5 November 2008

Lwandle Technologies
Gabriel Place
1 Gabriel Road
Plumstead
7800

Attention Craig Matthysen

CHEMICAL ANALYSIS: Water samples (Order No.:)
Samples received: 30/10/08
Analysis completed: 03/11/08 Re-analysed: 05/11/08
Sample description: Seawater in sealed plastic bottles.

Lab	Sample	Total Suspended Solids
No	Id	in mg/L
34861	**Koeberg-1**	3
34862	**Koeberg-1 -10m**	2
34863	**Koeberg-2**	3
34864	**Koeberg-2 -10m**	3
34865	**Koeberg-3**	4
34866	**Koeberg-4**	9
34867	**Koeberg-5**	10
34868	**K30 S1-4m**	5
34869	**K30 S2-12m**	6
34870	**K30 S3-20m**	10
34871	**K30 S4-28m**	10

Andrew Pascall
MARINE ANALYTICAL SERVICES
Laboratory Manager

Sebastian Brown
MARINE ANALYTICAL SERVICES
Deputy Laboratory Manager

- Method not included in the scope of accreditation.

LWANDLE DATA REPORT

KOEBERG SITE – BIOFOULING PLATES RETRIEVAL

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

09 June 2009

Job No: LT-JOB-50

LWANDLE TECHNOLOGIES (PTY) LTD

Directors: C.P. Matthysen, M. Majodina, B.J. Spolander

1st floor Gabriel Place, 1 Gabriel Road, Plumstead, 7800, South Africa

Co Reg. No. 2003/015524/07

TABLE OF CONTENTS

1. INTRODUCTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report describes the procedures for collection of biofouling samples. Two plates were retrieved on October 18th 2008.

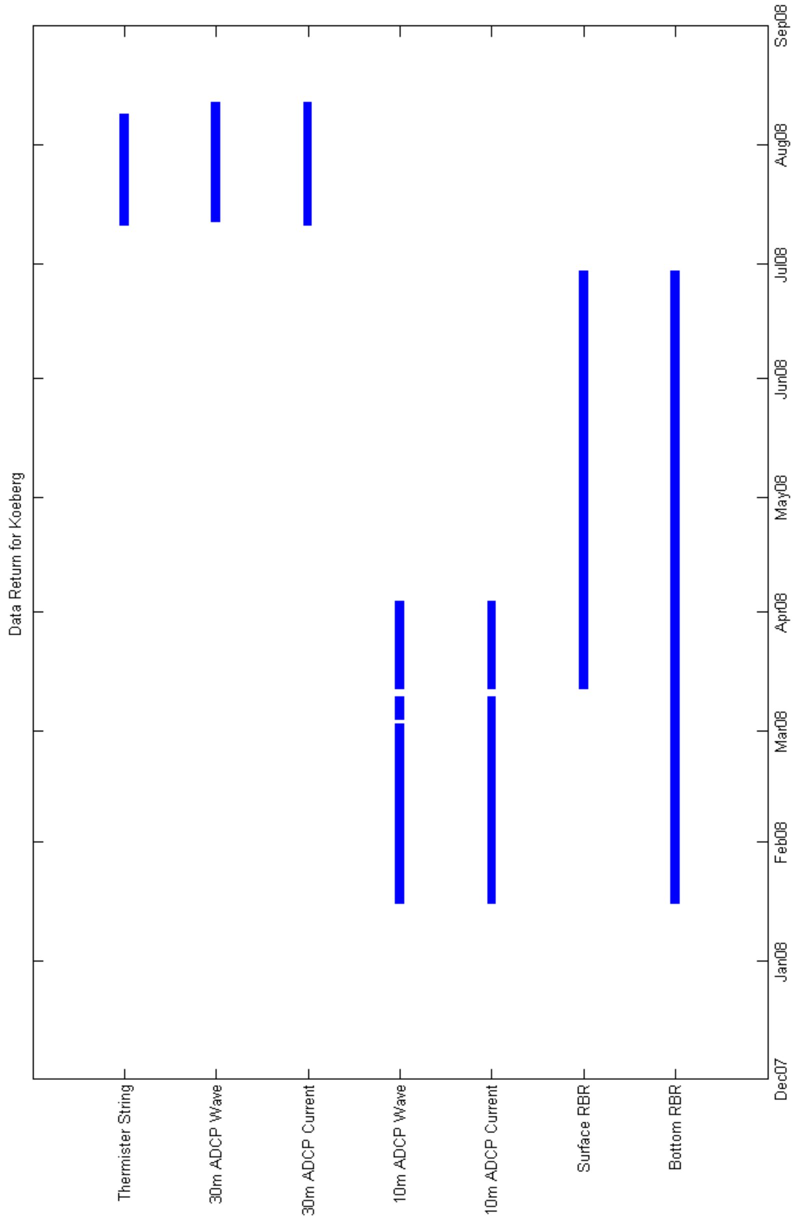


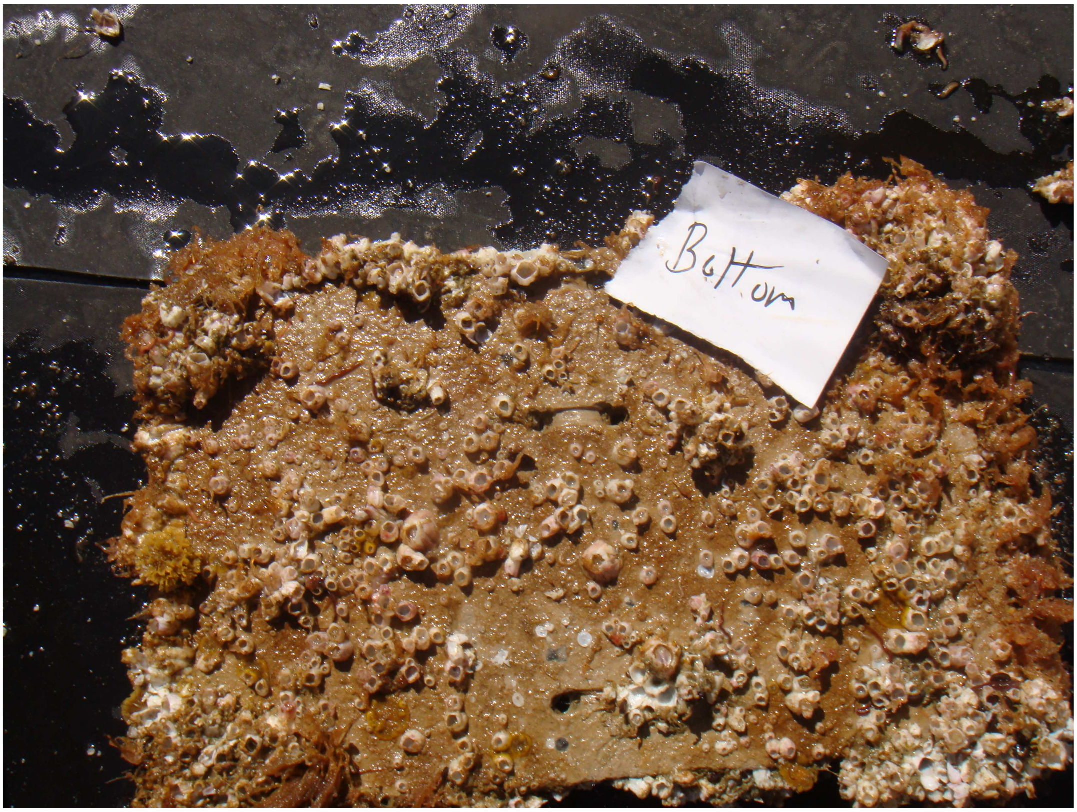
Figure 1: An indication of the data return at the Koeberg site since the beginning of the project.

2. METHOD.

The following standard procedure was followed:

- Two biofouling plates were retrieved – labelled *Top* and *Bottom*.
- Photographs of the plate and prominent features were taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates (asbestos side) was measured.
- The Biofouling organisms present on the plates were gently scraped into sample bottles and filled with seawater.
- Formaldehyde was added to a final 2-4% strength solution.
- 3-5 mg of $CaCO_3$ was added.
- Sample bottles were stored upright in the dark.

3. MEASUREMENTS AND PHOTOS TAKEN.



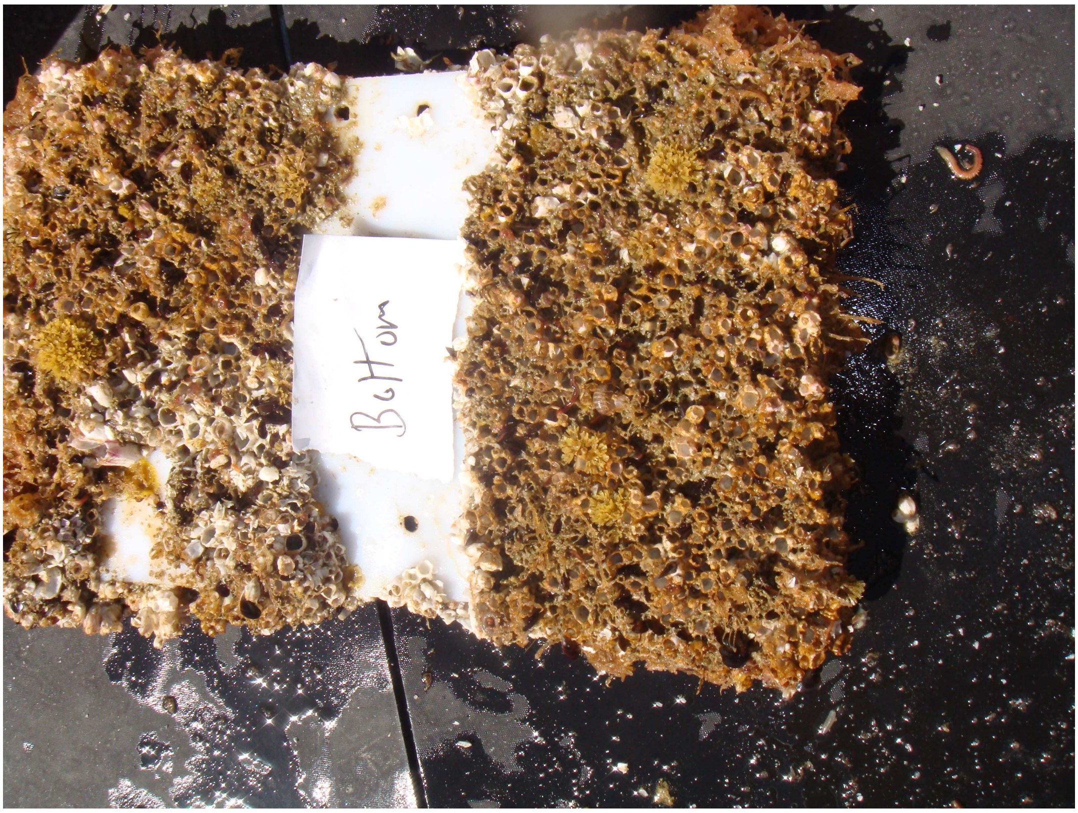
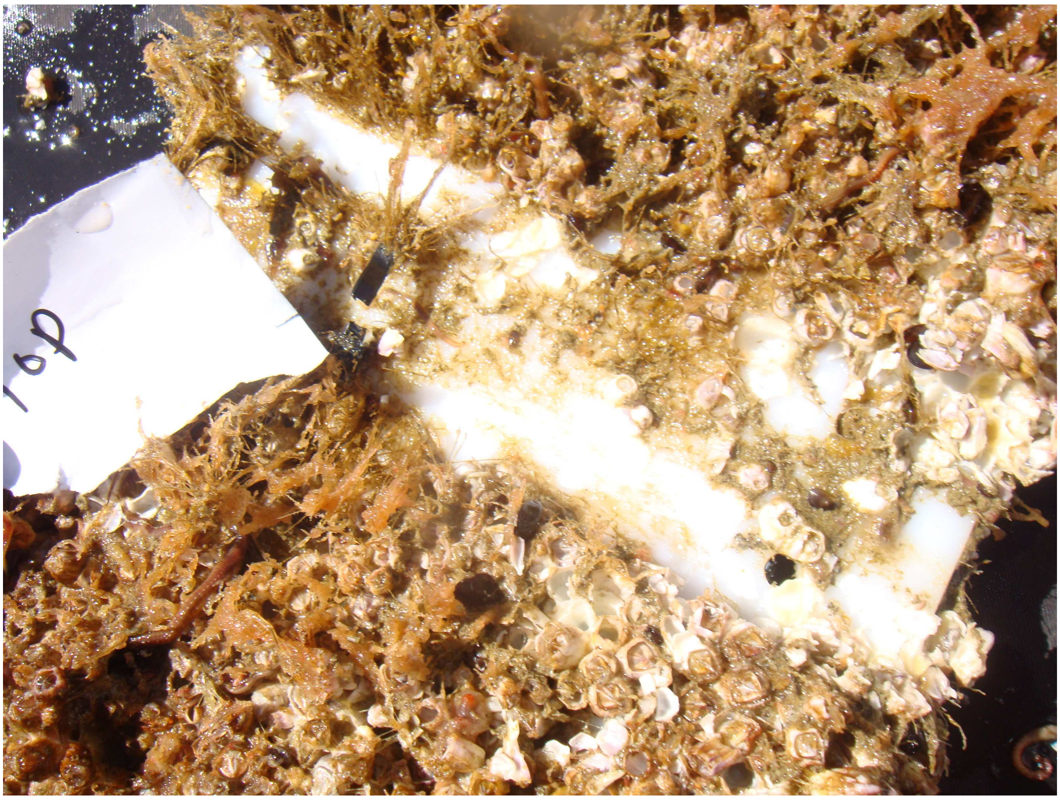


Figure 2: Both sides of the plate labelled “*Bottom*”.


Top


Top

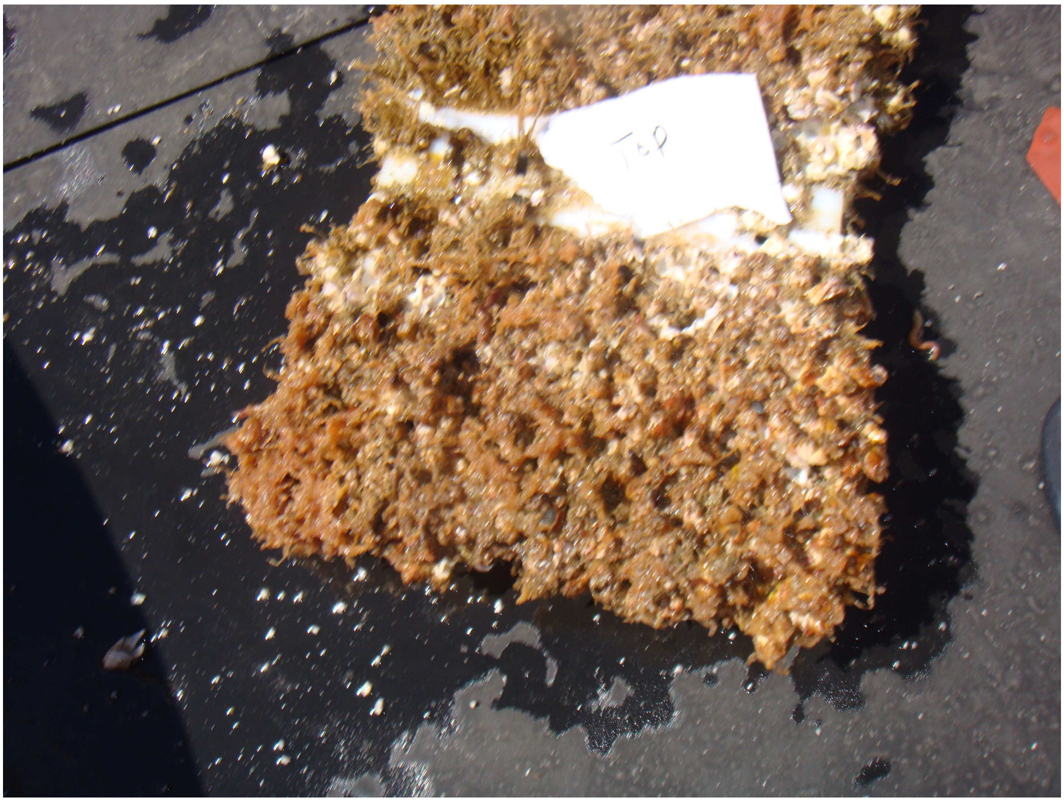


Figure 3: Both sides of the plate labelled "*Top*".

A total of 6 samples were collected (Table 1) and where possible, flora and fauna were separated. The average 'thickness' measurement for the top and bottom plates were 1.6 cm and 1.75 cm respectively.

Table 1: Description of water sample taken.

Bottle Label	Description
Top S1-1	Top plate – combination of flora and fauna, mostly barnacles, worms and algae. Higher density of algae on the corners.
Top S1-2	
Top S2	
Btm S1-1	Bottom plate, Flora – algae, small sponges.
Btm S1-2	Bottom plate, Fauna – barnacles, worms, small crabs.
Btm S2	Bottom plate – combination of both flora and fauna. Higher density at the corners of the plate.

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT FOUR

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

4 February 2009

Job No: LT-JOB-50

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 4 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary for 10m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-8.9	99.96	0.5053	0.0845	0.0693	0.0121	240.29
-8.5	99.96	0.4938	0.0881	0.0722	0.0136	240.83
-8.2	99.96	0.5104	0.0904	0.0736	0.0139	242.23
-7.8	99.96	0.5300	0.0921	0.0752	0.0142	244.55
-7.5	99.96	0.5342	0.0937	0.0769	0.0147	250.76
-7.1	99.96	0.5475	0.0949	0.0778	0.0152	255.61
-6.8	99.96	0.5360	0.0963	0.0792	0.0161	260.69
-6.4	99.96	0.5705	0.098	0.0807	0.0170	265.57
-6.1	99.96	0.6120	0.0999	0.0819	0.0179	272.45
-5.7	99.96	0.6132	0.1022	0.0836	0.0196	275.74
-5.4	99.96	0.5933	0.1041	0.0851	0.0206	281.83
-5.0	99.96	0.6006	0.1058	0.0872	0.0226	286.42
-4.7	99.91	0.6086	0.109	0.0897	0.0250	290.36
-4.3	99.91	0.6444	0.1109	0.0917	0.0277	295.1
-4.0	99.96	0.6424	0.1141	0.0950	0.0306	297.41
-3.6	99.96	0.6427	0.1174	0.0973	0.0334	300.78
-3.3	99.96	0.6469	0.1205	0.0990	0.0363	303.76
-2.9	99.96	0.6412	0.1247	0.1014	0.0385	307.78
-2.6	99.96	0.6389	0.129	0.1038	0.0415	311.14
-2.2	99.96	0.6637	0.1328	0.1062	0.0441	314.86
-1.9	99.96	0.6622	0.1369	0.1108	0.0455	324.70
-1.5	99.96	0.7630	0.147	0.1167	0.0495	341.43
-1.2	96.79	0.7994	0.1581	0.1221	0.0549	352.66
-0.8	69.41	0.7685	0.1596	0.1206	0.0579	3.49

Table 2 – Waves summary for 10m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	92.38	3.02	0.69	1.70	0.56
Tp (s)	92.38	17.00	3.20	12.46	1.73
Dp (^{o})	92.38	287.75	176.75	258.80	7.83

Table 3 – Current flow summary for 30m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-26.8	100.00	0.2322	0.0614	0.0339	0.0060	164.60
-26.3	99.92	0.3408	0.0663	0.0368	0.0081	162.64
-25.8	99.88	0.4279	0.0696	0.0397	0.0095	164.06
-25.3	99.88	0.4499	0.0713	0.0408	0.0101	161.07
-24.8	99.80	0.4088	0.0731	0.0409	0.0103	158.93
-24.3	99.88	0.3475	0.0747	0.0417	0.0108	157.45
-23.8	99.88	0.2597	0.0764	0.0427	0.0116	154.90
-23.3	99.88	0.2682	0.0782	0.0433	0.0120	153.86
-22.8	99.96	0.2906	0.0796	0.0448	0.0124	151.84
-22.3	99.96	0.2673	0.0805	0.0450	0.0130	152.68
-21.8	99.96	0.2830	0.0820	0.0456	0.0133	150.24
-21.3	100.00	0.2899	0.0835	0.0473	0.0139	148.88
-20.8	100.00	0.3014	0.0842	0.0478	0.0141	146.27
-20.3	100.00	0.3316	0.0854	0.0486	0.0137	144.64
-19.8	99.92	0.2924	0.0861	0.0484	0.0123	143.11
-19.3	100.00	0.3125	0.0871	0.0495	0.0114	138.97
-18.8	100.00	0.3020	0.0879	0.0498	0.0100	135.23
-18.3	100.00	0.3048	0.0893	0.0513	0.0085	131.28
-17.8	99.96	0.3184	0.0904	0.0526	0.0077	124.03
-17.3	100.00	0.3113	0.0919	0.0535	0.0069	112.31
-16.8	100.00	0.3064	0.0935	0.0548	0.0062	96.04
-16.3	100.00	0.3214	0.0946	0.0555	0.0054	81.41
-15.8	100.00	0.3284	0.0955	0.0564	0.0054	63.26
-15.3	100.00	0.3183	0.0964	0.0567	0.0062	51.51
-14.8	100.00	0.3260	0.0971	0.0576	0.0066	37.56
-14.3	100.00	0.3301	0.0977	0.0586	0.0074	22.04
-13.8	100.00	0.3431	0.0983	0.0586	0.0081	13.41
-13.3	100.00	0.3342	0.0992	0.0592	0.0094	5.51
-12.8	100.00	0.3587	0.0995	0.0596	0.0099	355.54
-12.3	100.00	0.3718	0.0996	0.0604	0.0115	350.19
-11.8	100.00	0.3634	0.0996	0.0612	0.0127	342.55
-11.3	100.00	0.3656	0.0996	0.0624	0.0139	336.66
-10.8	100.00	0.3809	0.1002	0.0629	0.0157	330.64
-10.3	100.00	0.4169	0.1007	0.0640	0.0172	326.34
-9.8	100.00	0.4182	0.1018	0.0655	0.0199	320.27
-9.3	100.00	0.4284	0.1030	0.0672	0.0223	316.37
-8.8	100.00	0.4227	0.1048	0.0691	0.0244	313.63
-8.3	100.00	0.4401	0.1069	0.0715	0.0269	311.21
-7.8	100.00	0.4621	0.1092	0.0739	0.0301	307.86
-7.3	100.00	0.4870	0.1108	0.0757	0.0328	305.36
-6.8	100.00	0.4690	0.1134	0.0773	0.0357	303.30
-6.3	100.00	0.4856	0.1165	0.0787	0.0389	301.12

-5.8	100.00	0.4968	0.1201	0.0804	0.0417	300.08
-5.3	99.96	0.5105	0.1238	0.0818	0.0445	298.33
-4.8	99.96	0.5094	0.1268	0.0834	0.0443	298.25
-4.3	100.00	0.4985	0.1287	0.0842	0.0405	298.66
-3.8	99.92	0.5038	0.1270	0.0832	0.0331	304.50
-3.3	99.92	0.4800	0.1285	0.0842	0.0442	316.68
-2.8	99.88	0.5342	0.1495	0.0920	0.0659	327.13
-2.3	96.80	0.5442	0.1823	0.1040	0.0881	330.20

Table 4 – Waves summary for 30m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	95.14	3.58	0.68	1.73	0.57
Tp (s)	95.14	16.90	5.00	11.94	1.90
Dp (^{o})	95.14	359.75	189.75	229.77	13.37

Table 5 – Water temperature and salinity summary for 10m RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100.00	12.28	15.58	9.62
Conductivity	100.00	39.71	43.78	36.00
Salinity (psu)	100.00	34.46	35.33	31.35

Table 6 – Water temperature and salinity summary for 30m RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100.00	10.84	12.07	9.48
Conductivity	100.00	38.23	39.60	31.17
Salinity (psu)	85.48	34.51	34.70	34.30

1.1 DATA RETURN FOR KOEBERG SITE.

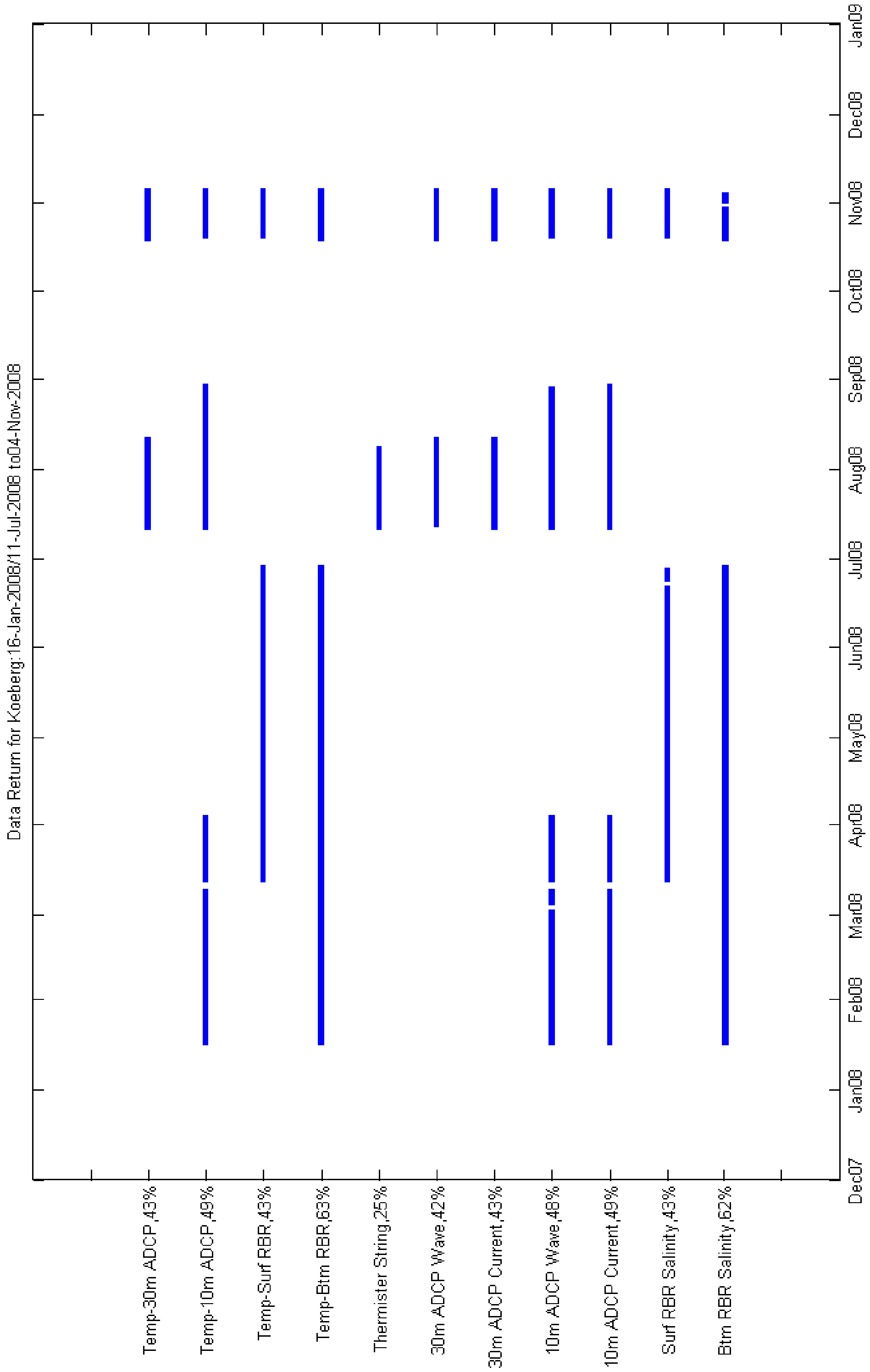


Figure 1: An indication of the data return (%) at the Koeberg site since the beginning of the project (Jan 16th 2008; July 11th 2008 for 30m ADCP and Thermister String). A break down of the temperature (Temp) return from all available instruments is given in the top 5 bars.

2. INTRODUCTION

2.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period October 18th 2008 - November 4th 2008 (Period 4). Recovery of the instruments was undertaken on Nov 4th and the redeployment on the 8th.

2.2 EQUIPMENT LIST

Lwandle provided the equipment as listed in Table 7 for the Koeberg site.

Table 7 – List of equipment provided.

Item	Operational (on site)	Spare (for whole project)
TRDI 600kHz ADCP	2	1
RBR XR420 CT logger	2	1
RBR Thermister String	0	0

2.3 MEASUREMENT LOCATION

The deployment locations of the moorings are recorded in Table 8.

Table 8 – Initial deployment locations.

Instrument	Latitude (°S)	Longitude (°E)
10m ADCP with RBR logger	33.6701	18.4150
30m ADCP with RBR logger	33.6757	18.3898

3. OPERATIONS

3.1 SUMMARY OF EVENTS.

SV4 – November 4th 2008.
Recovery of the 10m and 30m ADCPs as well as the RBR-CT loggers that was attached on the respective frames was undertaken.

SV4 – November 8th 2008.
Redeployment of all the instruments was successful. No units were replaced during this visit: at the 30m Site, ADCP s/n 10119 and RBR s/n 12997 and at the 10m Site, ADCP s/n 11424 and RBR s/n 12995.

3.2 INSTRUMENT CONFIGURATIONS

The deployed instrumentation configurations are given in this section and completed deployment / recovery sheets are given as an appendix (Section 7, page 51) to this report.

3.2.1 600kHz ADCP

Table 9 – Instrument configuration for the 10m ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	11424
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.35 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

Table 10 – Instrument configuration for the 30m ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	10119
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.5 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

3.2.2 RBR XR420 CT LOGGER

Table 11 – Instrument configuration for T&C Mooring Line.

Parameter	Configuration
XR 420 Temperature and Conductivity	s/n 12995 (10m) and s/n 12997 (30m)
Sampling and Averaging	Sample at 1Hz for 1 minute every 10 minutes

3.2.3 Biofouling Mooring

Table 12 – Instrument configuration for Biofouling Mooring Line.

Parameter	Configuration
Biofouling Plates	3 plates (20cmx20cm) at 3m and 3 plates (20cmx20cm) at 8m
Edgetech Acoustic Release	s/n 32385 release code 642102

3.3 RECOVER AND REDEPLOYMENT METHODOLOGY

3.3.1 T&C mooring and Thermister string

The T&C mooring line was deployed by lowering the array down via a rope through the anchor weights. The mooring line is recovered using divers to undo a single shackle that connects the mooring line to the anchor weights. Divers reattach the line onto the weights, after the instruments have been serviced.

The Thermister string is attached to the 30m ADCP frame. The string comprises of four nodes at 30m, 29m, 19m, and 9m below the surface.

3.3.2 ADCP mooring

The ADCP Frame is lowered to the bottom and moved into position by divers, who also attach chain sections that act as anchors. To retrieve the frame divers have to locate the mooring, take off the anchor chains and surface the frame using air lift bags that they attach.

Figure 2 – ADCP frame with 600KHz instrument.

3.3.3 Biofouling mooring

The biofouling mooring line was deployed by lowering the array down via a rope through the anchor weights. Divers would locate the mooring line and retrieve a surface and bottom plate from the line at the required sampling periods.

4. DATA QUALITY CONTROL

4.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

4.1.1 Current processing

- The record was truncated to exclude times pre and post deployment.
- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 15’ W (both ADCP sites).
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP’s pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of 0.2ms^{-1} was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined.
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

4.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 15’ W (both ADCP sites).
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

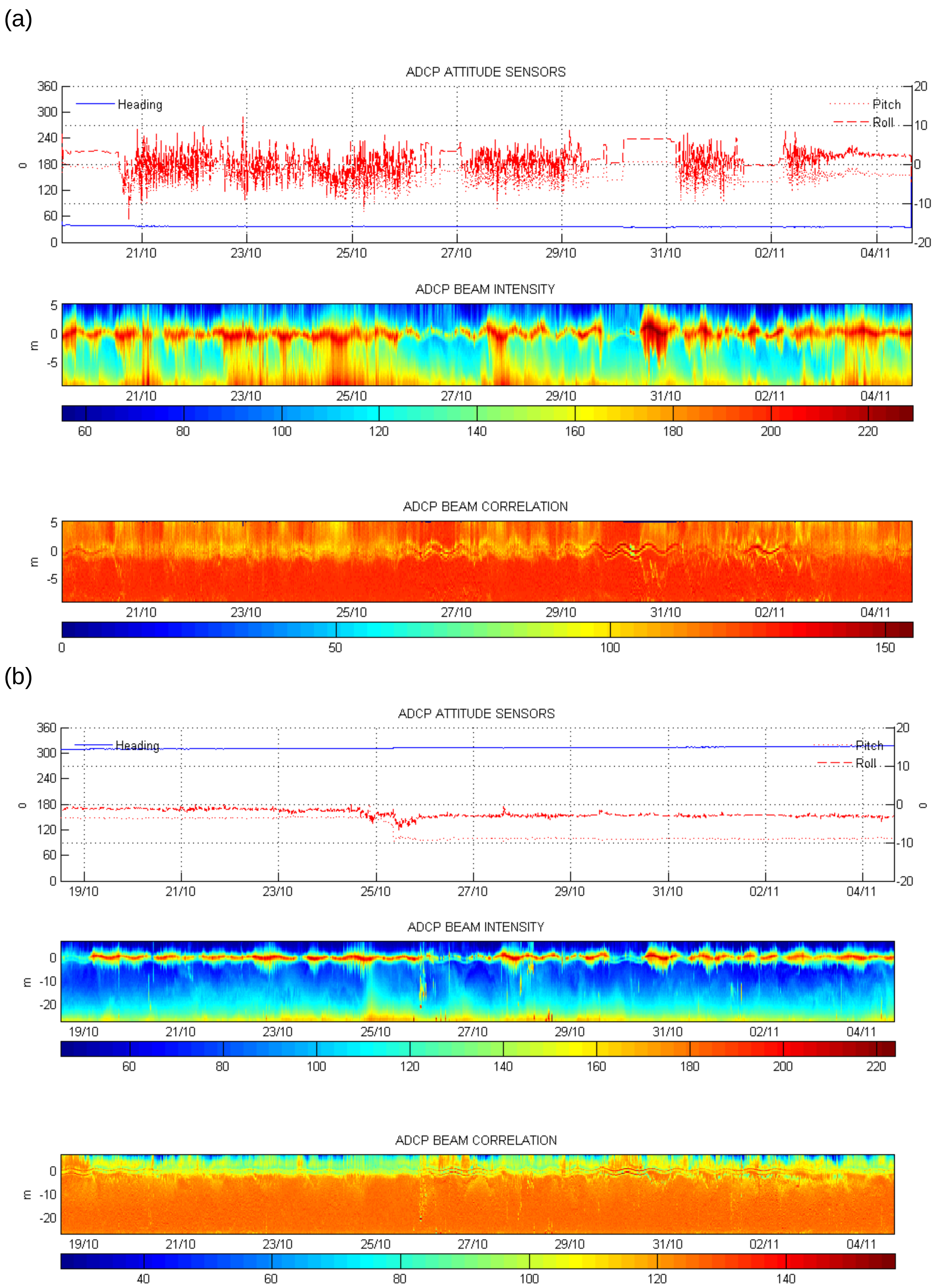


Figure 3: Quality control data from the (a) 10m and (b) 30m ADCPs. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

4.2 RBR-CT LOGGER AND THERMISTER STRING

The conductivity (from the CT-logger) and temperature data were exported directly from the RBR software into Matlab for further processing.

- The record was truncated to exclude times pre and post deployment.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.
- Salinity less than 34.3 psu were discarded for the 30m unit.

4.3 BIOFOULING.

The following standard procedure is normally followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates are measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 CaC03 chips are added.
- Sample bottles are stored upright in the dark.

Recovery of the biofouling plates was not scheduled.

4.4 WATER SAMPLE.

No water samples were collected.

5. DATA PRESENTATION

All data presented have been subject to the quality control procedures detailed in the previous section. Bad data have been excluded from all plots and calculations.

All plots in this section include a stamp that details the location, depth, time period and number of observations that the plot is based upon. Wherever possible, scaling of parameters has been kept constant throughout this section to facilitate comparison between plots and stations.

5.1 10M ADCP

5.1.1 Current Data

5.1.1.1 Time series plot

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

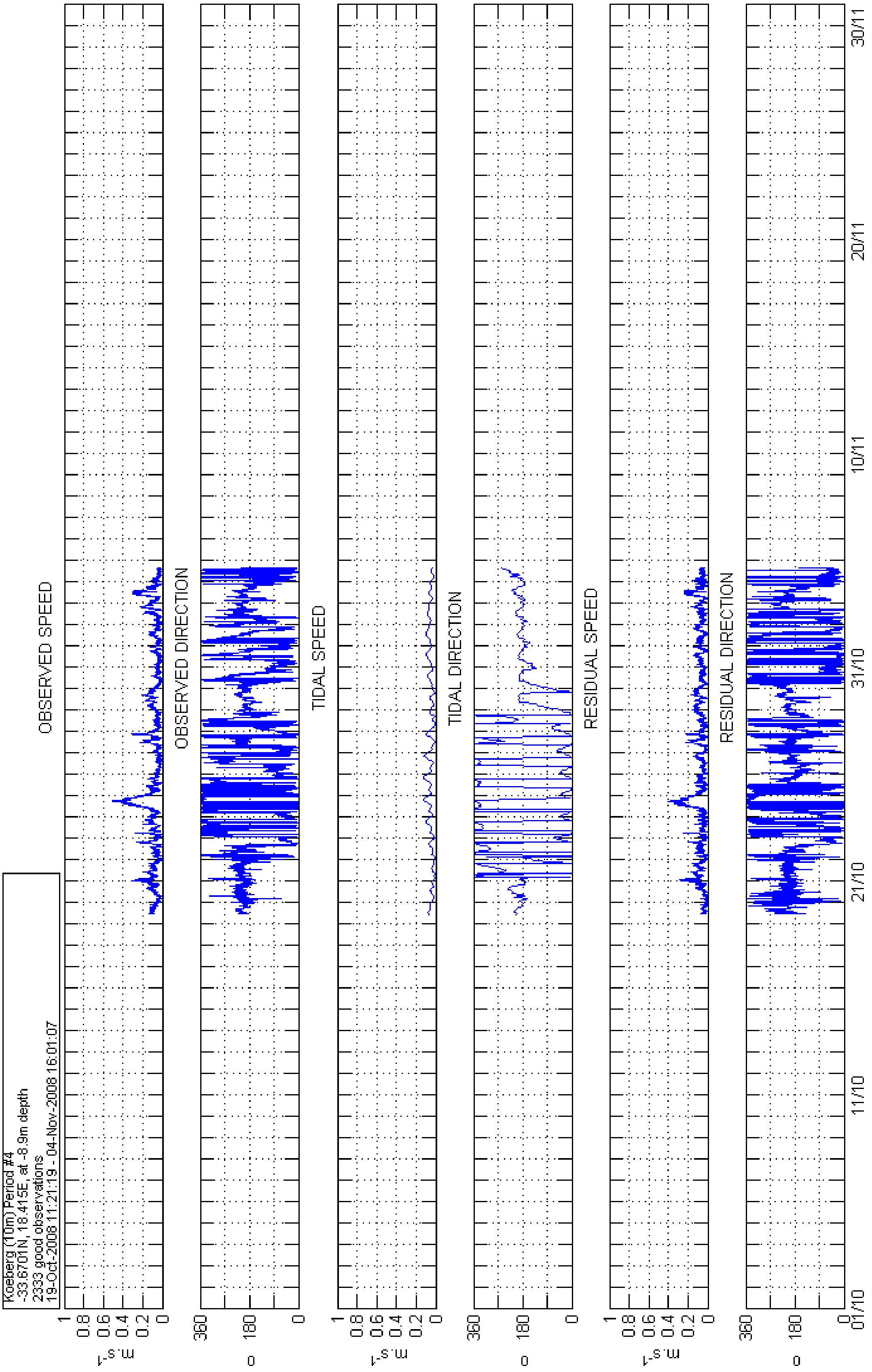


Figure 4: Time series plot of the 10m ADCP's current data at 8.9m.

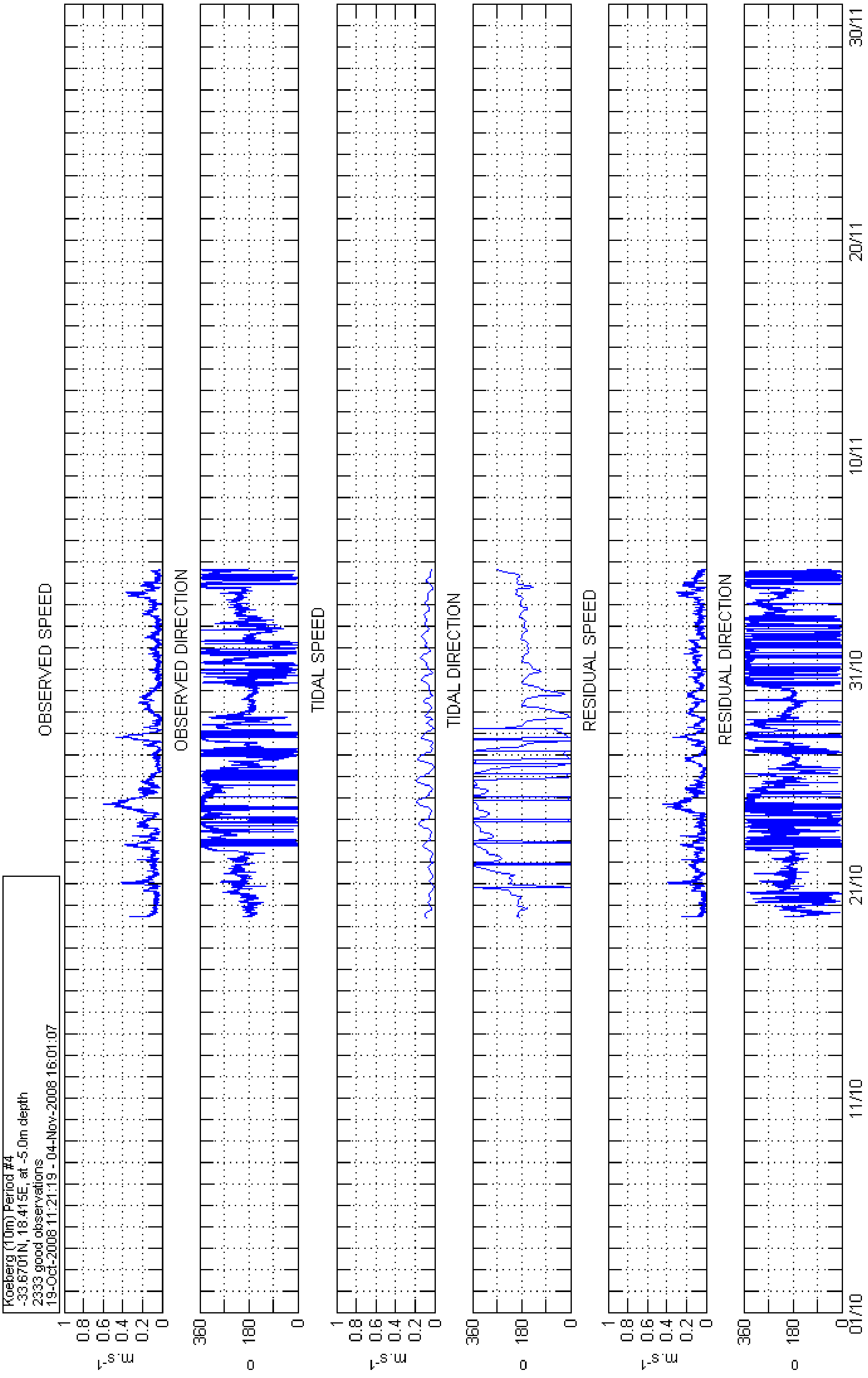


Figure 5: Time series plot of the 10m ADCP's current data at 5.0m.

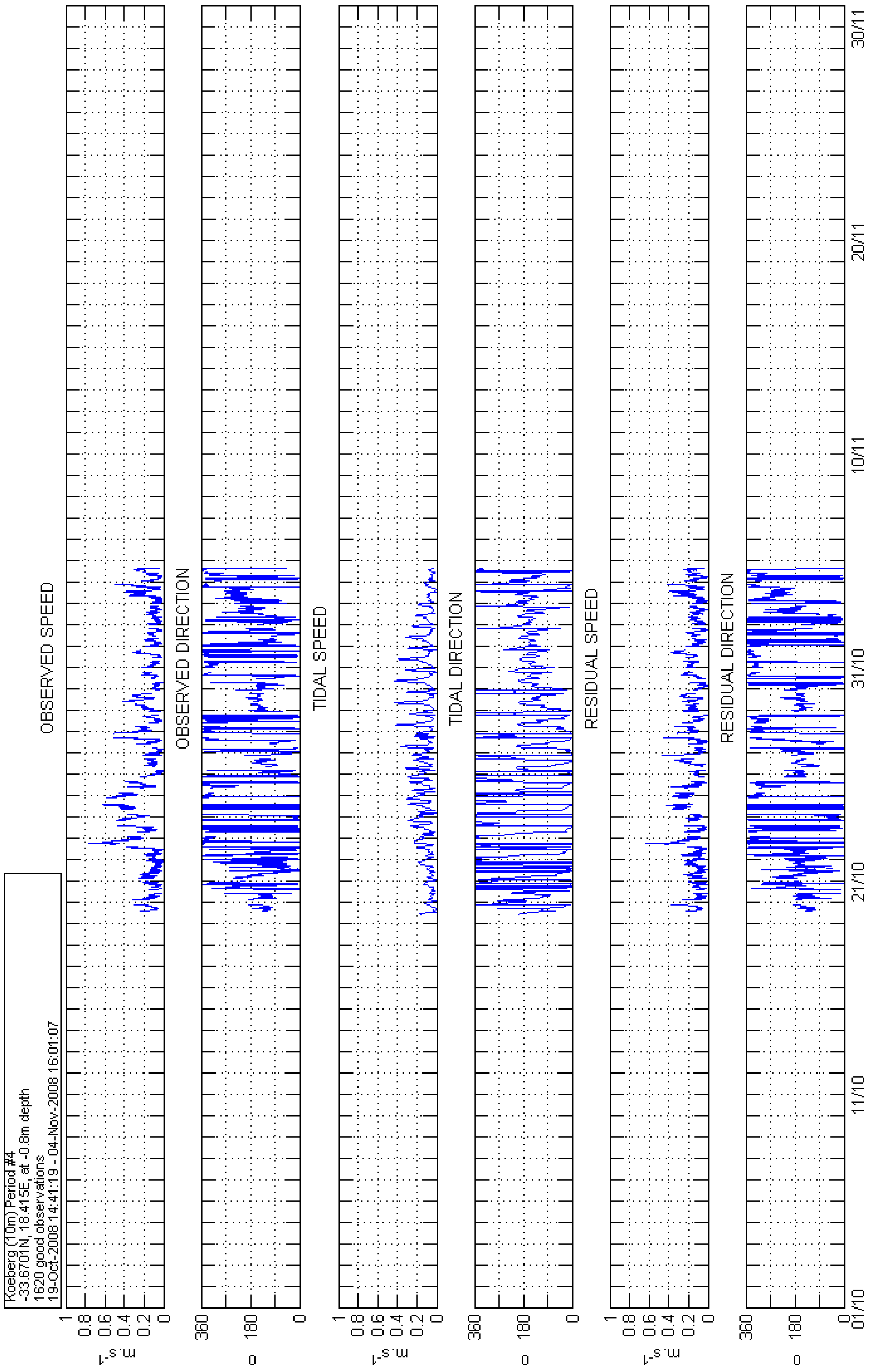


Figure 6: Time series plot of the 10m ADCP's current data at 0.8m.

5.1.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg (10m) Period #4
-33.6701N, 18.415E, at -8.9m depth
2333 good observations
19-Oct-2008 11:21:19 - 04-Nov-2008 16:01:07

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	4.24	4.93	5.83	5.44	4.07	3.43	2.57	4.07	6.73	9.09	5.40	3.81	3.00	2.57	2.31	4.37	71.88
0.1-0.2	2.27	1.33	0.60	0.39				0.73	3.09	6.04	4.59	0.30	0.17	0.21	0.51	1.37	21.60
0.2-0.3	1.37	0.26	0.09				0.04	0.04	0.30	1.07	0.47	0.09	0.09	0.13		0.13	4.07
0.3-0.4	1.50	0.04								0.26						0.13	1.93
0.4-0.5	0.34															0.09	0.43
0.5-0.6	0.09																0.09
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	9.82	6.56	6.52	5.83	4.07	3.43	2.61	4.84	10.12	16.46	10.46	4.20	3.26	2.91	2.83	6.09	100.00

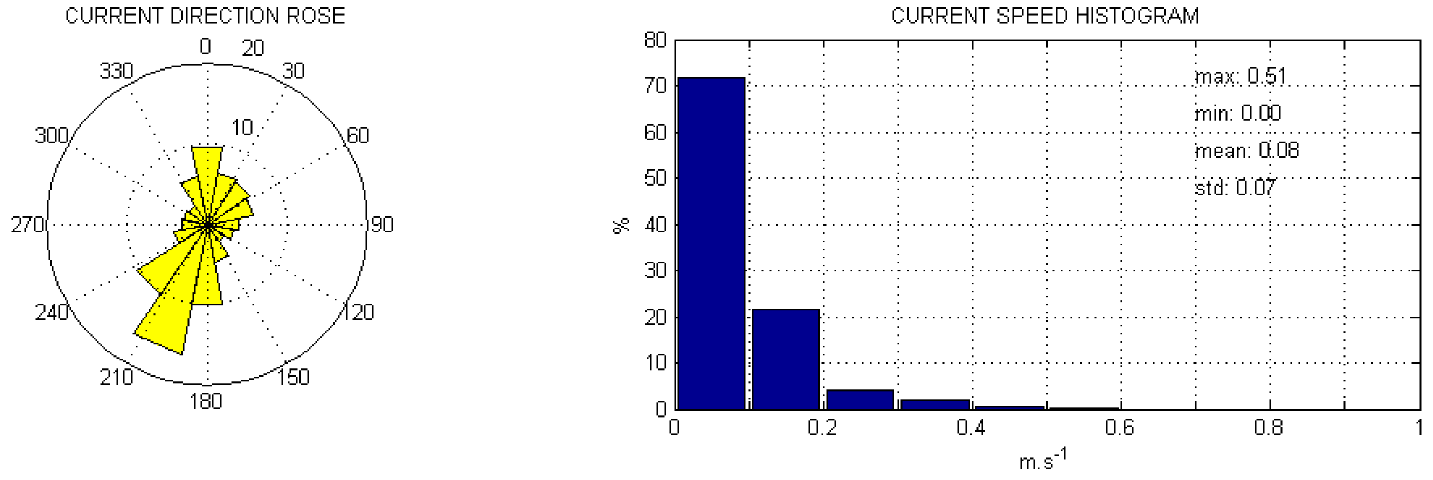


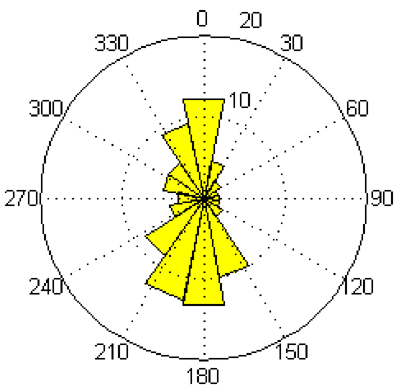
Figure 7: Summary plot of the 10m ADCP's current data at 8.9m.

Koeberg (10m) Period #4
-33.6701N, 18.415E, at -5.0m depth
2333 good observations
19-Oct-2008 11:21:19 - 04-Nov-2008 16:01:07

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	3.81	3.39	2.44	1.80	1.97	1.97	2.70	6.30	8.23	7.80	5.49	3.30	2.23	3.51	3.17	3.39	61.51
0.1-0.2	3.86	1.16					0.09	3.51	4.71	4.07	2.57	0.56	0.69	1.24	1.71	3.13	27.30
0.2-0.3	2.01							0.26	0.34	0.56	0.43	0.26	0.21	0.26	0.21	1.54	6.09
0.3-0.4	1.89	0.13							0.09	0.39	0.17	0.04	0.04	0.04		0.69	3.47
0.4-0.5	0.81											0.04		0.04		0.60	1.50
0.5-0.6	0.04															0.04	0.09
0.6-0.7	0.04																0.04
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	12.47	4.67	2.44	1.80	1.97	1.97	2.79	10.07	13.37	12.82	8.66	4.20	3.17	5.10	5.10	9.39	100.00

CURRENT DIRECTION ROSE



CURRENT SPEED HISTOGRAM

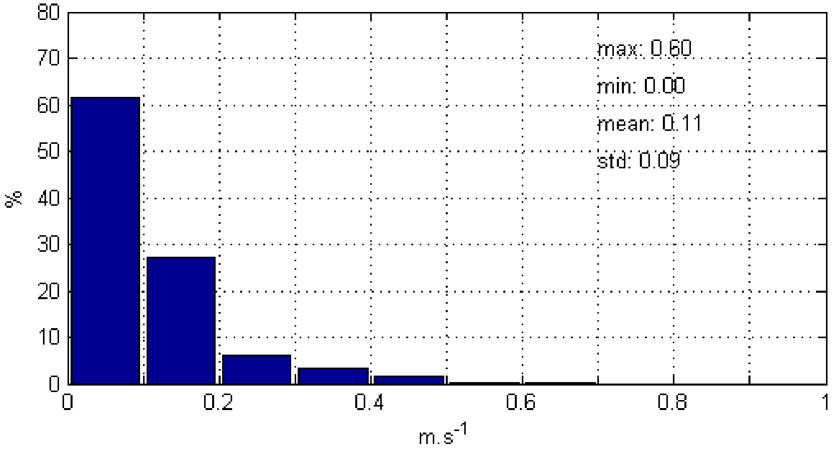


Figure 8: Summary plot of the 10m ADCP's current data at 5.0m.

Koeberg (10m) Period #4
-33.6701N, 18.415E, at -0.8m depth
1620 good observations
19-Oct-2008 14:41:19 - 04-Nov-2008 16:01:07

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	2.28	2.53	3.52	3.27	4.01	2.78	4.44	2.72	1.85	1.67	1.60	1.36	1.30	1.54	2.53	2.53	39.94
0.1-0.2	4.01	1.67	1.73	1.11	2.72	3.52	3.95	2.72	1.42	0.93	1.05	0.62	0.37	0.68	1.98	4.01	32.47
0.2-0.3	3.58	0.80	0.06		0.19	0.31	1.11	1.54	0.62	0.49	0.43	0.49	0.25	0.19	0.56	3.77	14.38
0.3-0.4	3.09	0.49					0.12	0.49	0.12	0.12	0.37	0.25	0.06		0.25	1.79	7.16
0.4-0.5	1.91	0.12						0.12							0.31	1.67	4.14
0.5-0.6	0.93														0.06	0.43	1.42
0.6-0.7	0.25															0.12	0.37
0.7-0.8	0.06															0.06	0.12
0.8-0.9																	0.00
0.9-1																	0.00
Σ	16.11	5.62	5.31	4.38	6.91	6.60	9.63	7.59	4.01	3.21	3.46	2.72	1.98	2.41	5.68	14.38	100.00

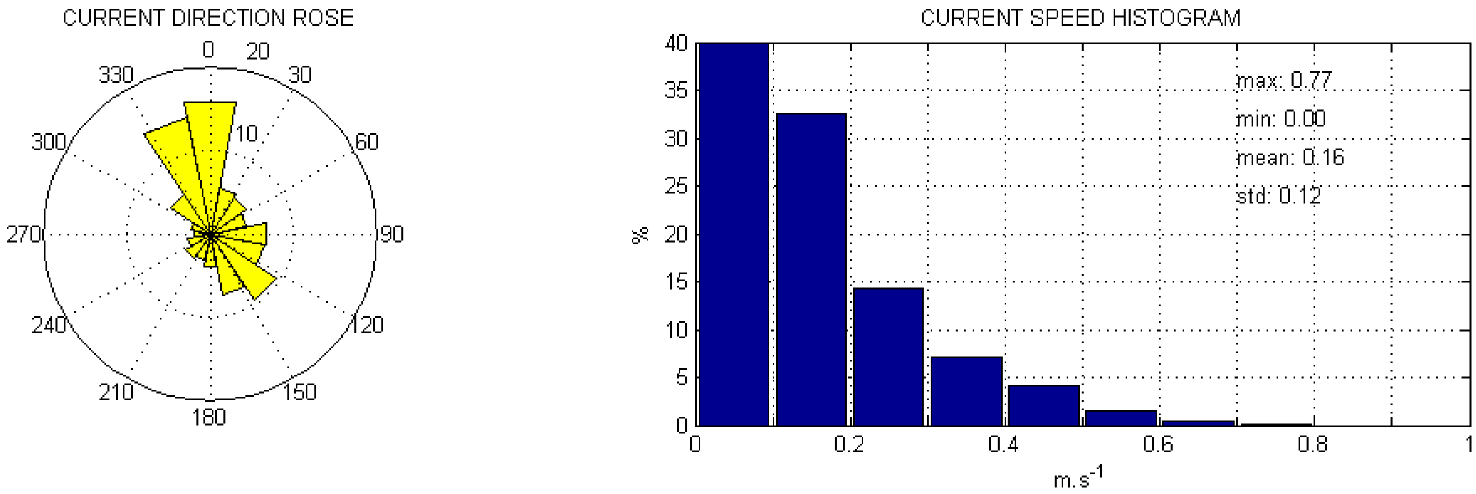


Figure 9: Summary plot of the 10m ADCP's current data at 0.8m.

5.1.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

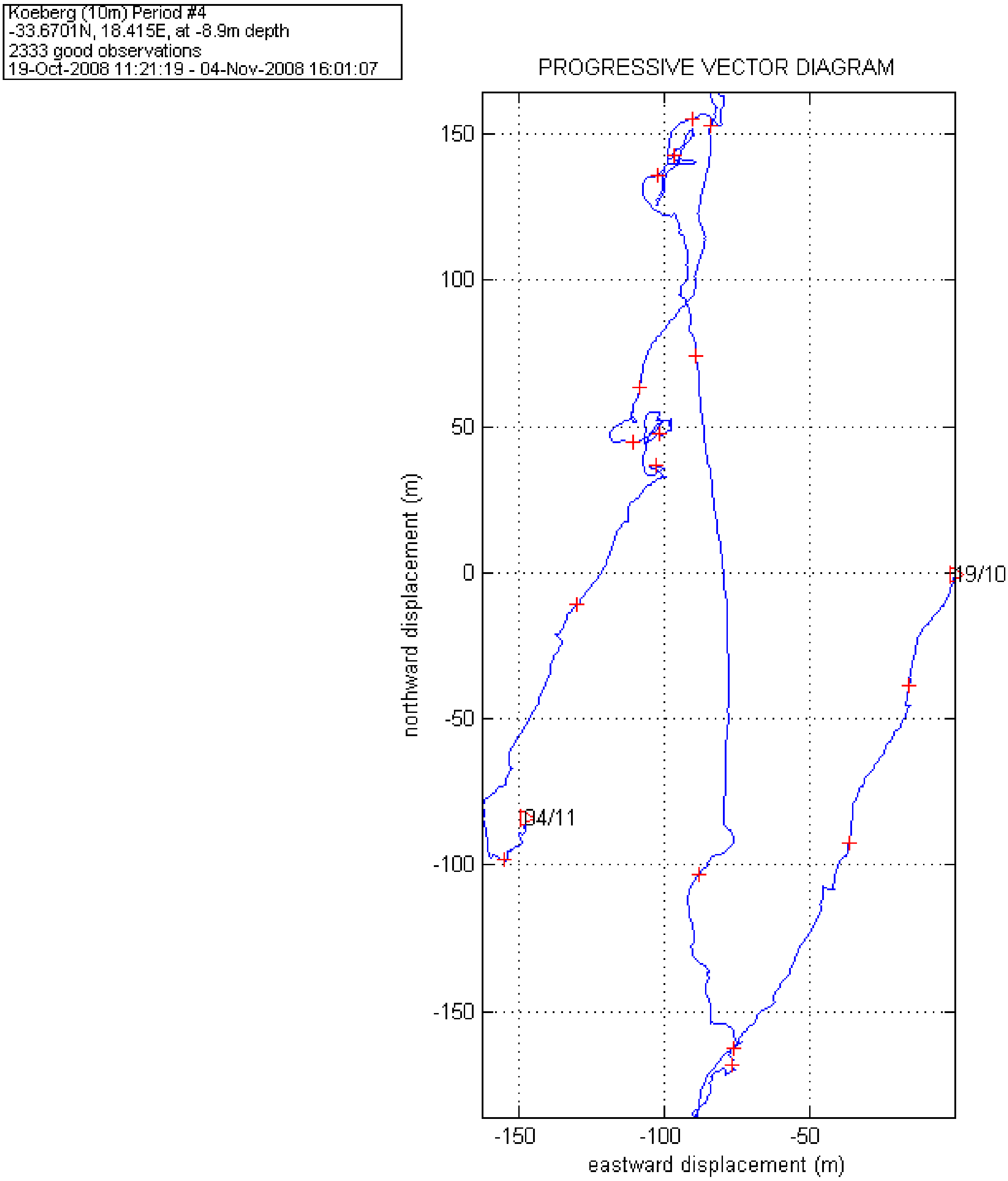


Figure 10: Progressive vector plot of current data at 8.9m.

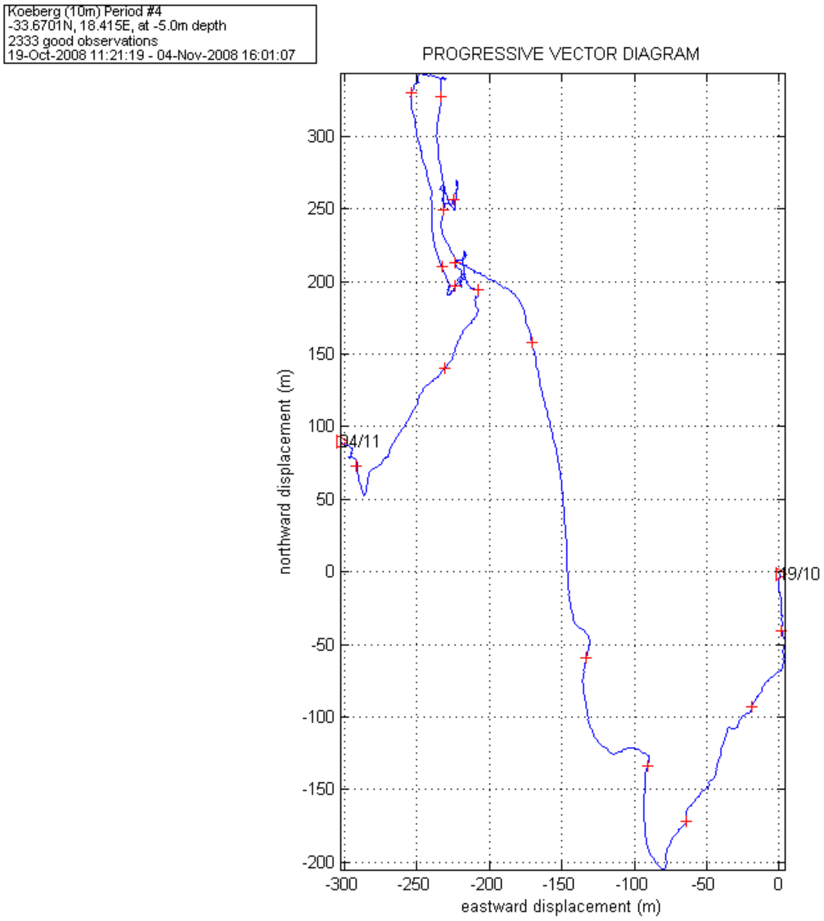


Figure 11: Progressive vector plot of current data at 5.0m.

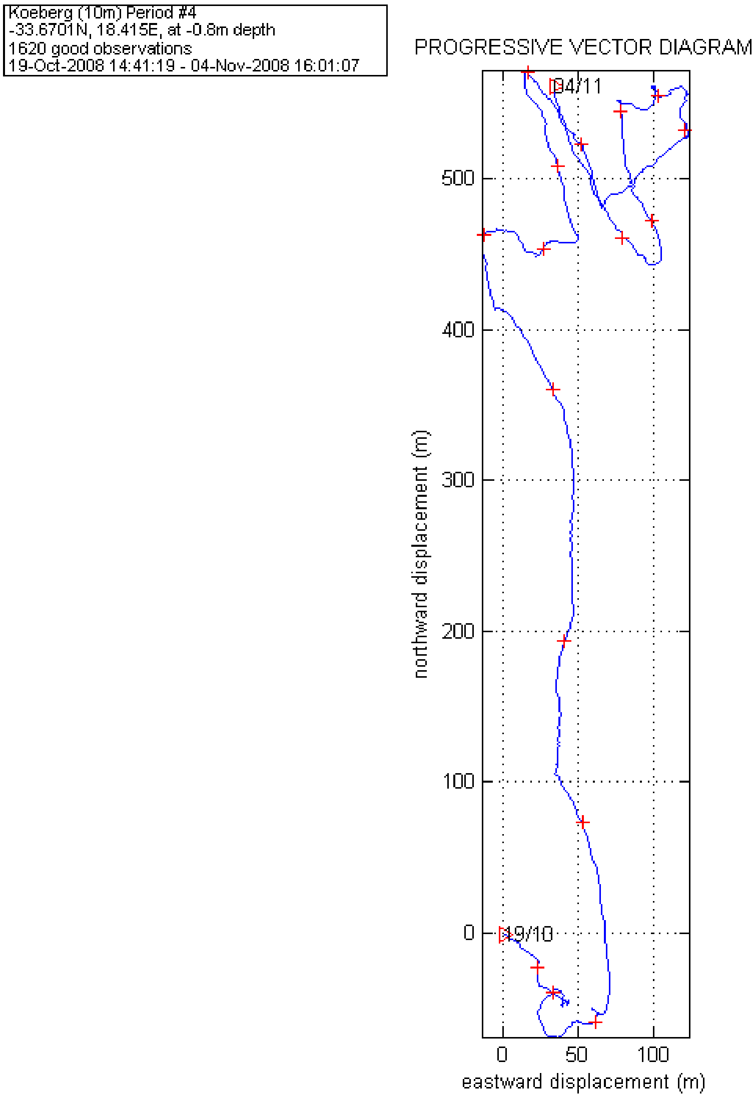


Figure 12: Progressive vector plot of current data at 0.8m.

5.1.2 Wave Data.

5.1.2.1 Hs and Tp summary plot

Figure 13 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.1.2.2 Hs and Dp summary plot

Figure 14 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.1.2.3 Tp and Dp summary plot

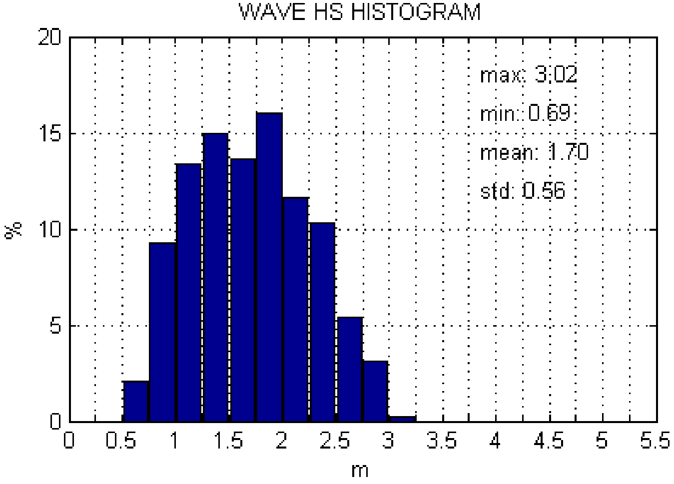
Figure 15 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

Koeberg (10m) Period #4
-33.6701N, 18.415E, at 10m depth
388 good observations
19-Oct-2008 11:21:00 - 04-Nov-2008 15:21:00

JOINT DISTRIBUTION OF HS AND TP

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5																0.00
0.5-0.75					0.26		1.80									2.06
0.75-1		0.26	0.26		1.80	2.58	3.09	1.29								9.28
1-1.25					0.52	4.12	8.51	0.26								13.40
1.25-1.5				0.26	0.52	6.19	6.96	0.52	0.52							14.95
1.5-1.75					0.52	4.38	7.47	1.29								13.66
1.75-2						5.41	5.67	4.64	0.26							15.98
2-2.25						2.58	6.44	2.58								11.60
2.25-2.5						1.55	5.67	3.09								10.31
2.5-2.75							3.09	2.32								5.41
2.75-3							1.80	1.29								3.09
3-3.25							0.26									0.26
3.25-3.5																0.00
3.5-3.75																0.00
3.75-4																0.00
4-4.25																0.00
4.25-4.5																0.00
4.5-4.75																0.00
4.75-5																0.00
5-5.25																0.00
5.25-5.5																0.00
Σ	0.00	0.26	0.26	0.26	3.61	26.80	50.77	17.27	0.77	0.00	0.00	0.00	0.00	0.00	0.00	100.00



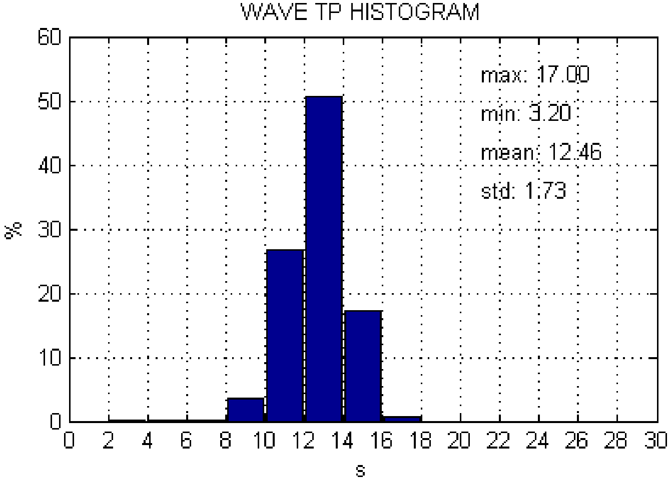
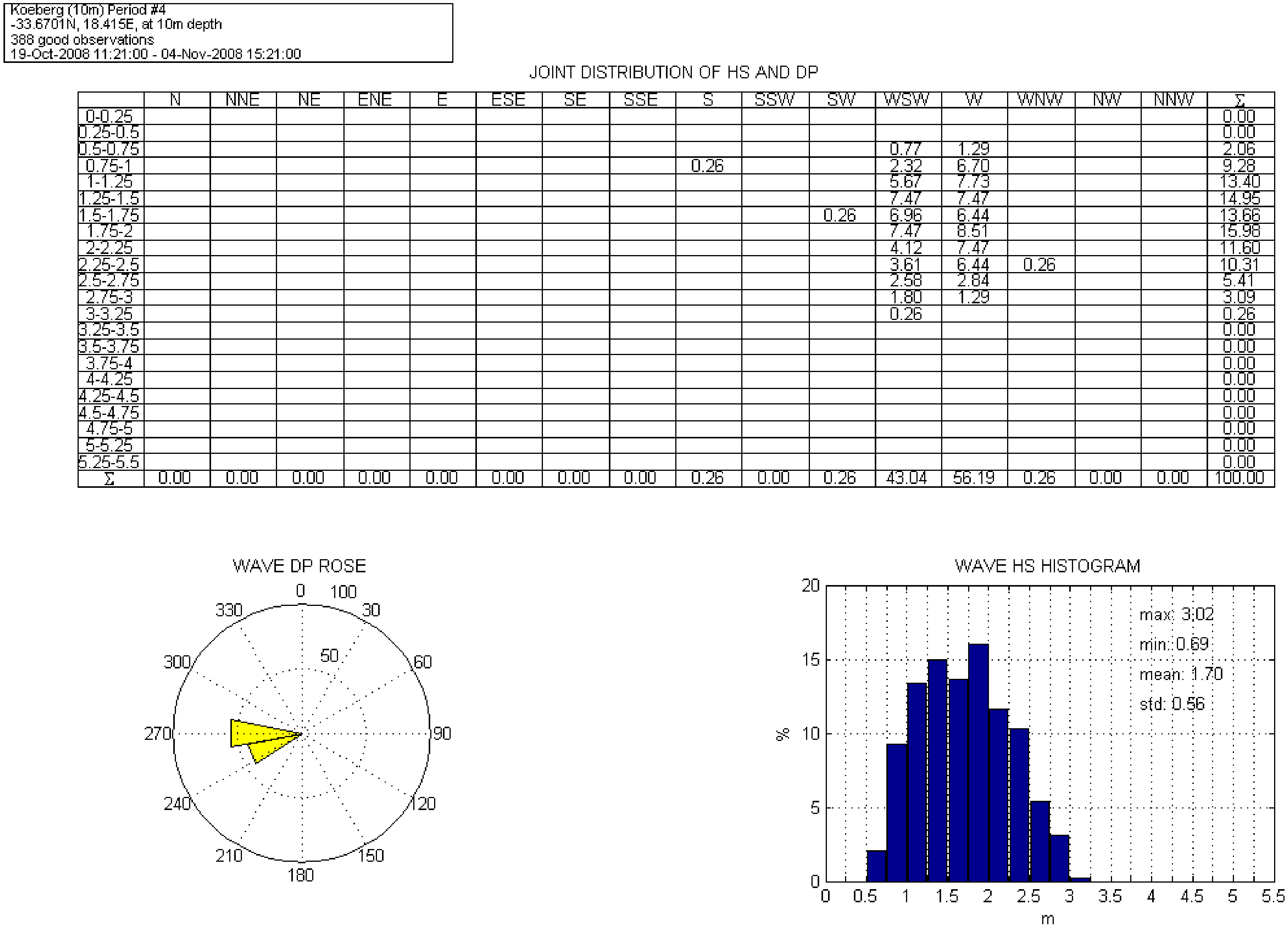


Figure 13: Summary plot of H_s and T_p.



Koeberg (10m) Period #4
-33.6701N, 18.415E, at 10m depth
388 good observations
19-Oct-2008 11:21:00 - 04-Nov-2008 15:21:00

JOINT DISTRIBUTION OF HS AND DP

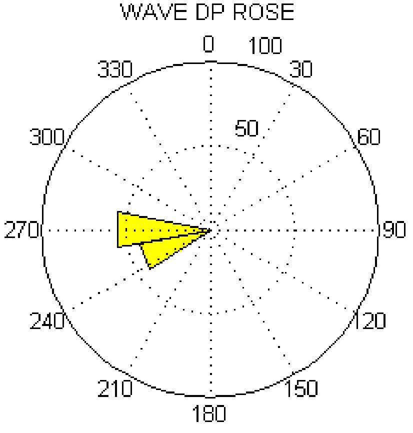
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5																	0.00
0.5-0.75												0.77	1.29				2.06
0.75-1									0.26			2.32	6.70				9.28
1-1.25												5.67	7.73				13.40
1.25-1.5												7.47	7.47				14.95
1.5-1.75											0.26	6.96	6.44				13.66
1.75-2												7.47	8.51				15.98
2-2.25												4.12	7.47				11.60
2.25-2.5												3.61	6.44	0.26			10.31
2.5-2.75												2.58	2.84				5.41
2.75-3												1.80	1.29				3.09
3-3.25												0.26					0.26
3.25-3.5																	0.00
3.5-3.75																	0.00
3.75-4																	0.00
4-4.25																	0.00
4.25-4.5																	0.00
4.5-4.75																	0.00
4.75-5																	0.00
5-5.25																	0.00
5.25-5.5																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.26	43.04	56.19	0.26	0.00	0.00	100.00

Figure 14: Summary plot of H_s and D_p.

Koeberg (10m) Period #4
-33.6701N, 18.415E, at 10m depth
388 good observations
19-Oct-2008 11:21:00 - 04-Nov-2008 15:21:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4									0.26								0.26
4-6													0.26				0.26
6-8													0.26				0.26
8-10												1.80	1.80				3.61
10-12											0.26	11.60	14.95				26.80
12-14												22.16	28.35	0.26			50.77
14-16												7.22	10.05				17.27
16-18												0.26	0.52				0.77
18-20																	0.00
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.26	43.04	56.19	0.26	0.00	0.00	100.00



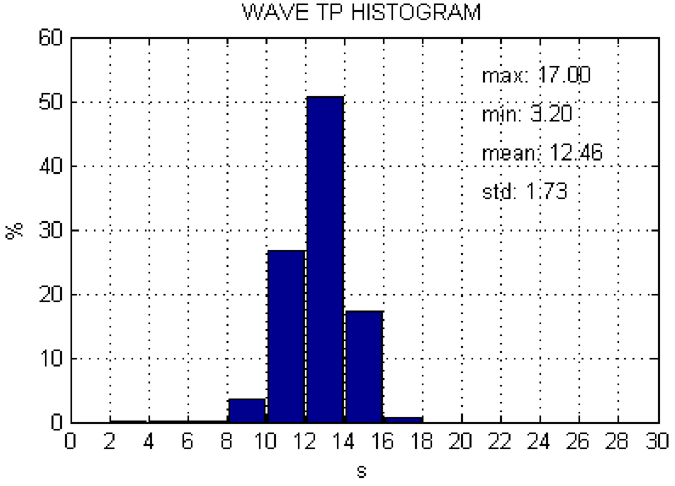


Figure 15: Summary plot of T_p and D_p.

5.1.2.4 Wave spectral plot

Figure 16 displays wave spectral plots for a significant wave event. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

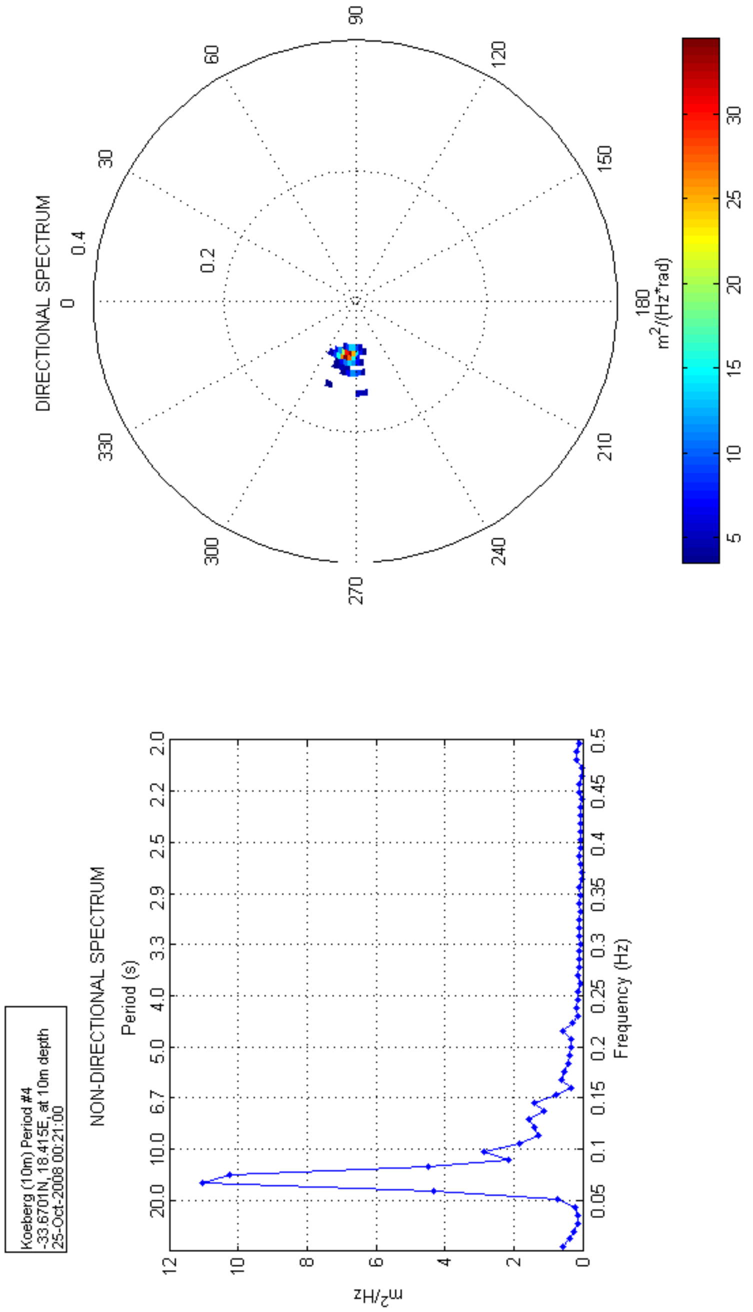


Figure 16: Wave spectra for 25th of October 2008 at 00:21:00.

5.2 30M ADCP

5.2.1 Current Data

5.2.1.1 Time series plot

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

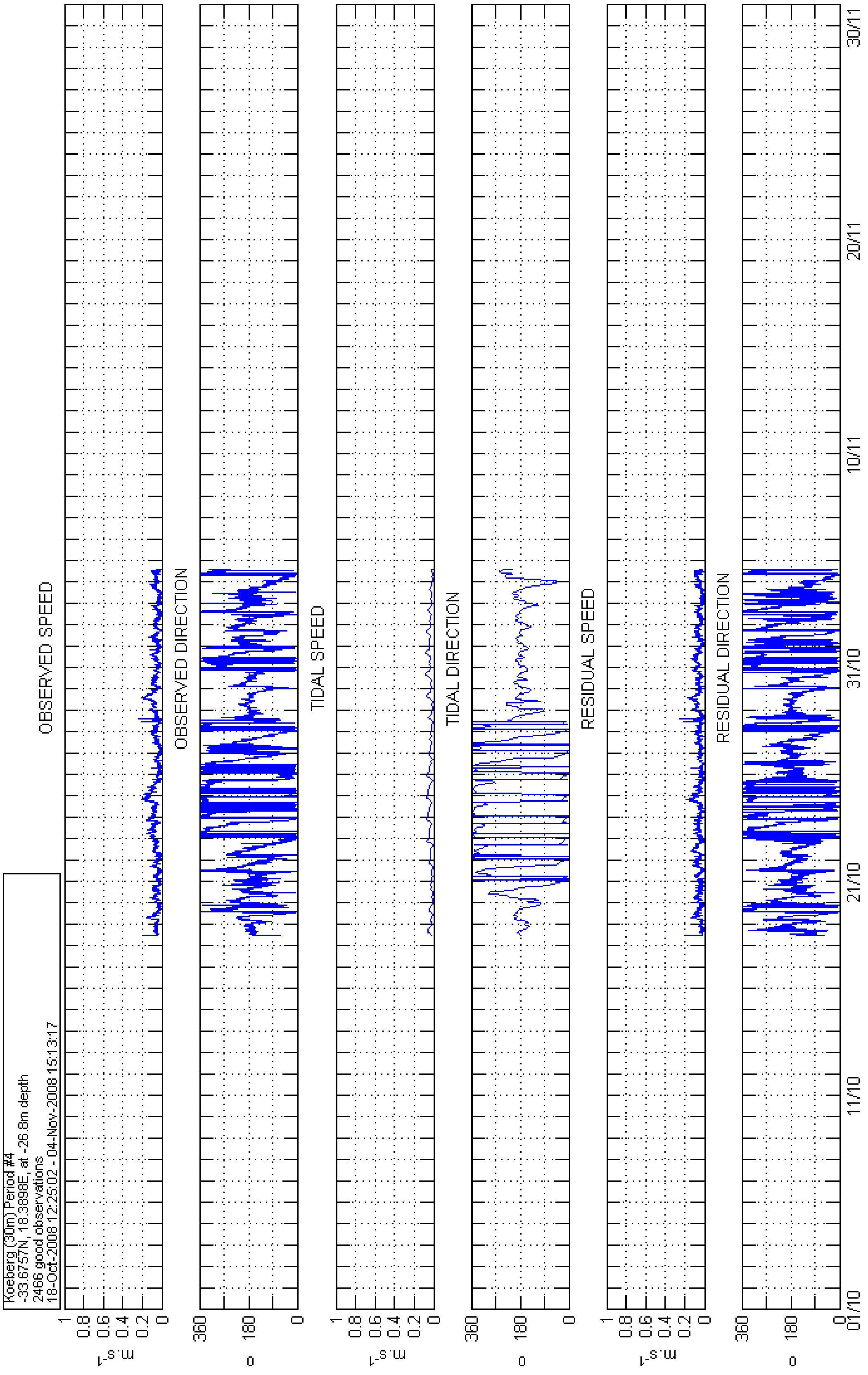


Figure 17: Time series plot of the 30m ADCP's current data at 26.8m.

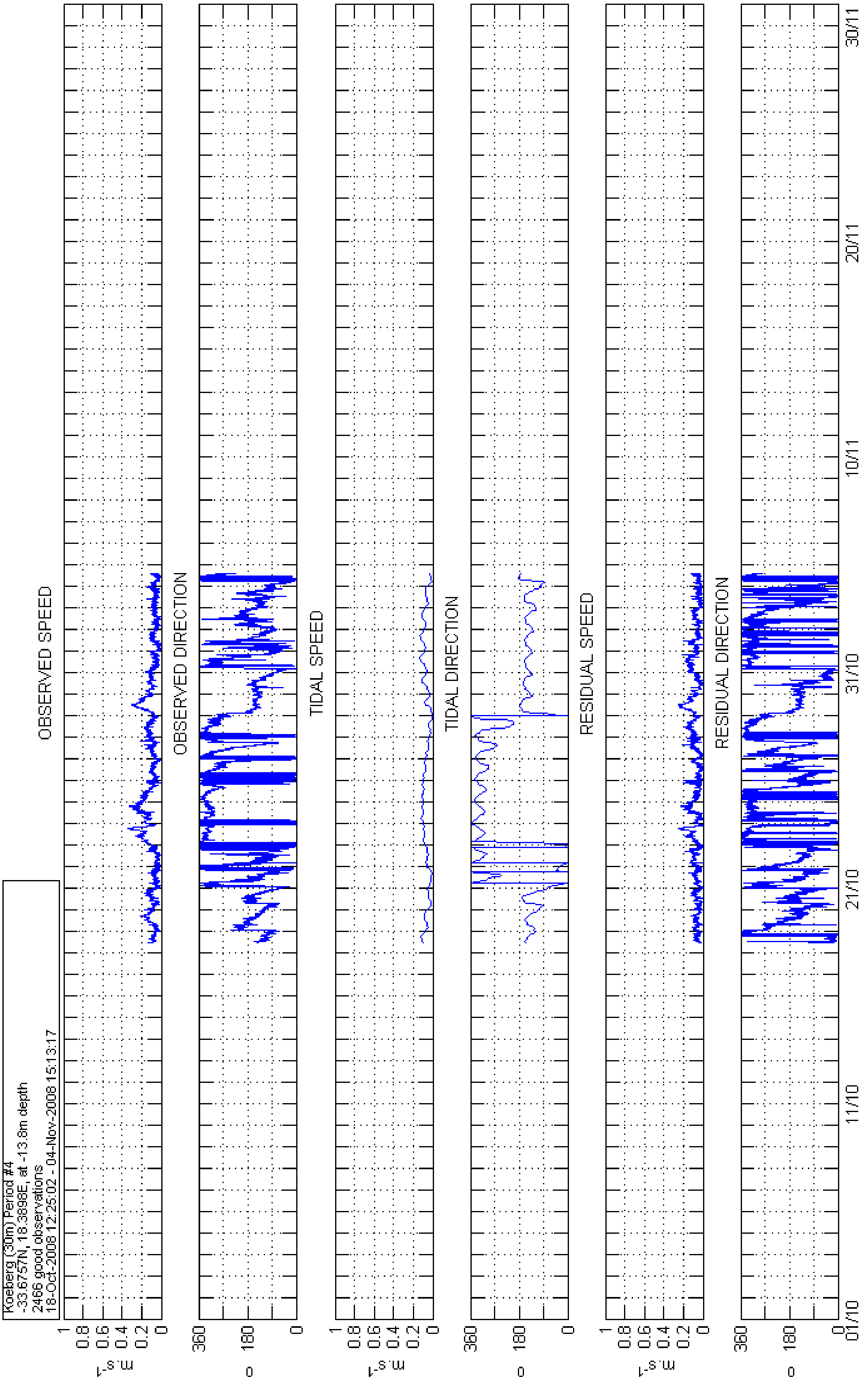


Figure 18: Time series plot of the 30m ADCP's current data at 13.8m.

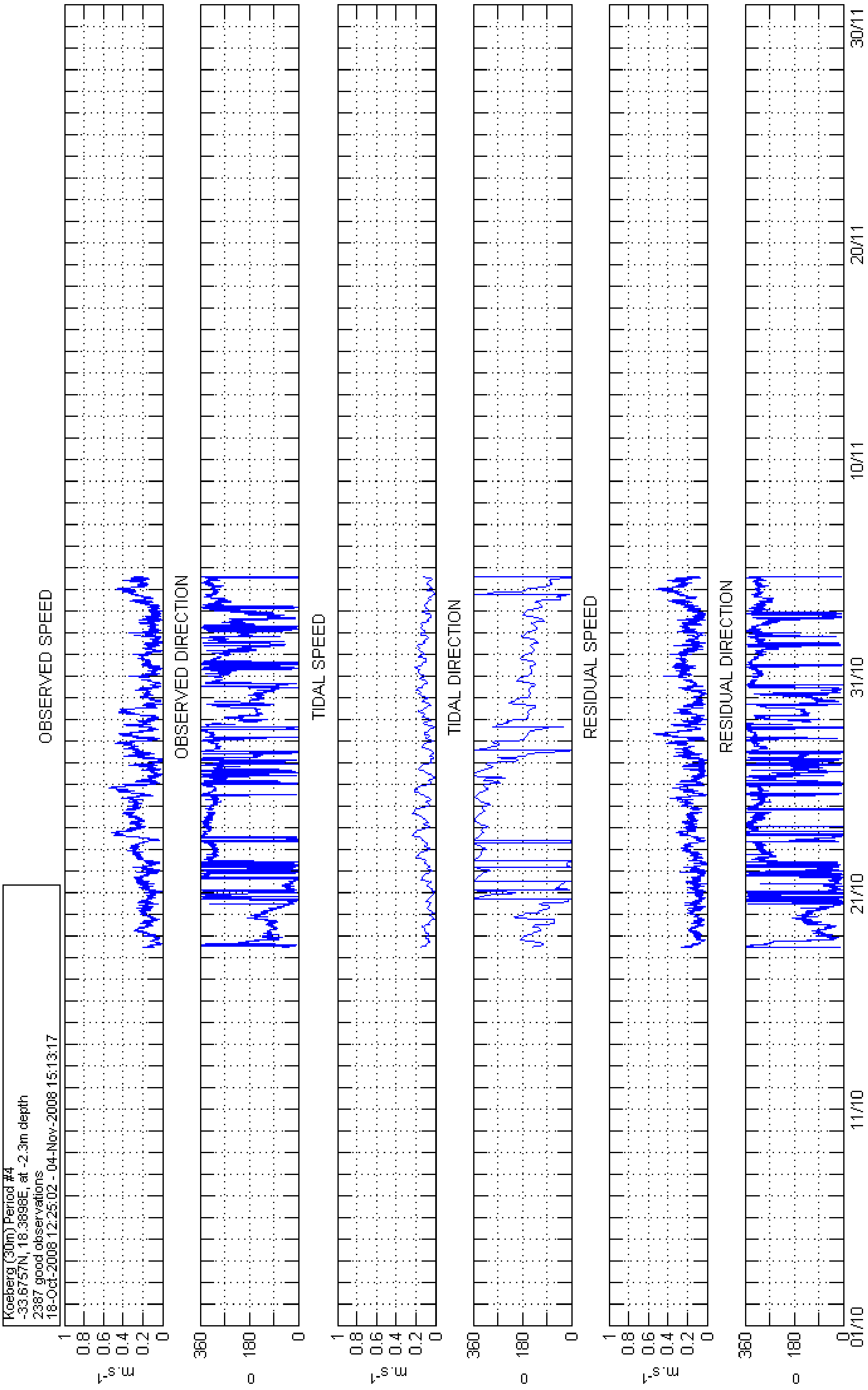


Figure 19: Time series plot of the 30m ADCP's current data at 2.3m.

5.2.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg (30m) Period #4
-33.6757N, 18.3898E, at -26.8m depth
2466 good observations
18-Oct-2008 12:25:02 - 04-Nov-2008 15:13:17

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	7.34	4.54	3.49	4.14	4.95	5.35	5.47	9.61	10.83	8.88	6.65	3.53	2.51	1.91	3.81	6.04	89.05
0.1-0.2	2.23	1.42	0.20	0.12	0.20	0.24	0.04	0.45	1.54	0.93	0.41	0.45	0.08	0.04	0.16	2.11	10.62
0.2-0.3	0.04					0.04	0.04		0.12							0.08	0.32
0.3-0.4																	0.00
0.4-0.5																	0.00
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	9.61	5.96	3.69	4.26	5.15	5.64	5.56	10.06	12.49	9.81	7.06	3.97	2.60	1.95	3.97	8.23	100.00

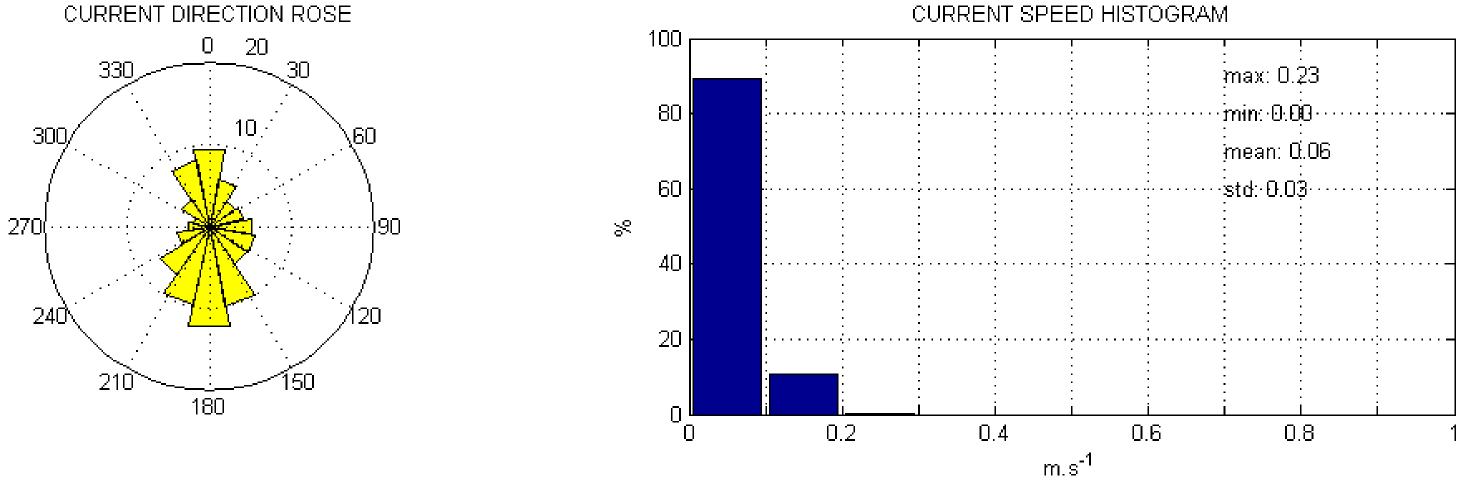
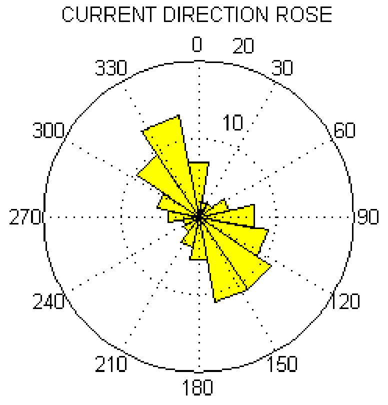


Figure 20: Summary plot of the 30m ADCP's current data at 26.8m.

Koeberg (30m) Period #4
-33.6757N, 18.3898E, at -13.8m depth
2466 good observations
18-Oct-2008 12:25:02 - 04-Nov-2008 15:13:17

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	3.81	1.62	1.70	3.00	6.08	7.30	6.97	5.35	4.10	3.69	1.99	1.74	3.49	3.41	3.57	4.38	62.21
0.1-0.2	3.24	0.24	0.24	1.05	1.22	1.82	3.73	4.38	1.50	0.36	0.28	0.28	0.45	1.82	4.06	6.20	30.90
0.2-0.3							0.53	1.50						0.12	1.70	2.39	6.24
0.3-0.4							0.04	0.04							0.24	0.32	0.65
0.4-0.5																	0.00
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	7.06	1.87	1.95	4.06	7.30	9.12	11.27	11.27	5.60	4.06	2.27	2.03	3.93	5.35	9.57	13.30	100.00



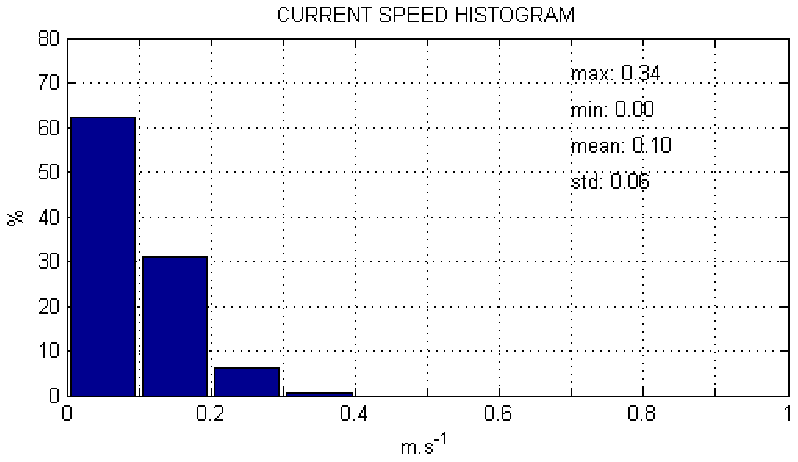


Figure 21: Summary plot of the 30m ADCP’s current data at 13.8m.

Koeberg (30m) Period #4
-33.6757N, 18.3898E, at -2.3m depth
2387 good observations
18-Oct-2008 12:25:02 - 04-Nov-2008 15:13:17

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	2.14	1.84	0.88	1.30	1.30	1.51	0.96	1.30	1.01	1.34	1.47	1.30	1.72	2.47	2.30	2.09	24.93
0.1-0.2	4.52	3.73	1.68	0.75	2.89	2.60	2.30	2.51	1.26	1.09	0.67	1.09	1.89	2.60	3.06	3.98	36.61
0.2-0.3	2.01	1.13	0.67	0.21	0.75	0.88	0.71	0.80	0.08	0.13	0.13	0.21	0.54	2.76	6.58	6.37	23.96
0.3-0.4	0.34						0.46	0.88					0.17	2.09	4.82	2.35	11.10
0.4-0.5	0.17						0.08	0.29						0.08	1.38	1.13	3.14
0.5-0.6														0.17	0.04	0.04	0.25
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	9.17	6.70	3.23	2.26	4.94	4.99	4.52	5.78	2.35	2.56	2.26	2.60	4.32	10.18	18.18	15.96	100.00

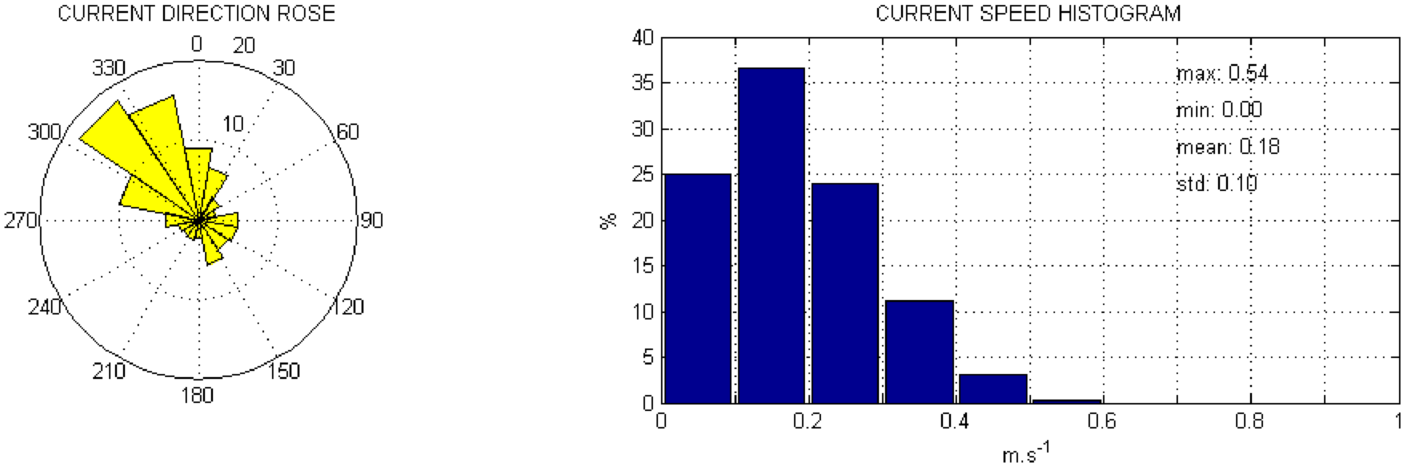


Figure 22: Summary plot of the 30m ADCP's current data at 2.3m.

5.2.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

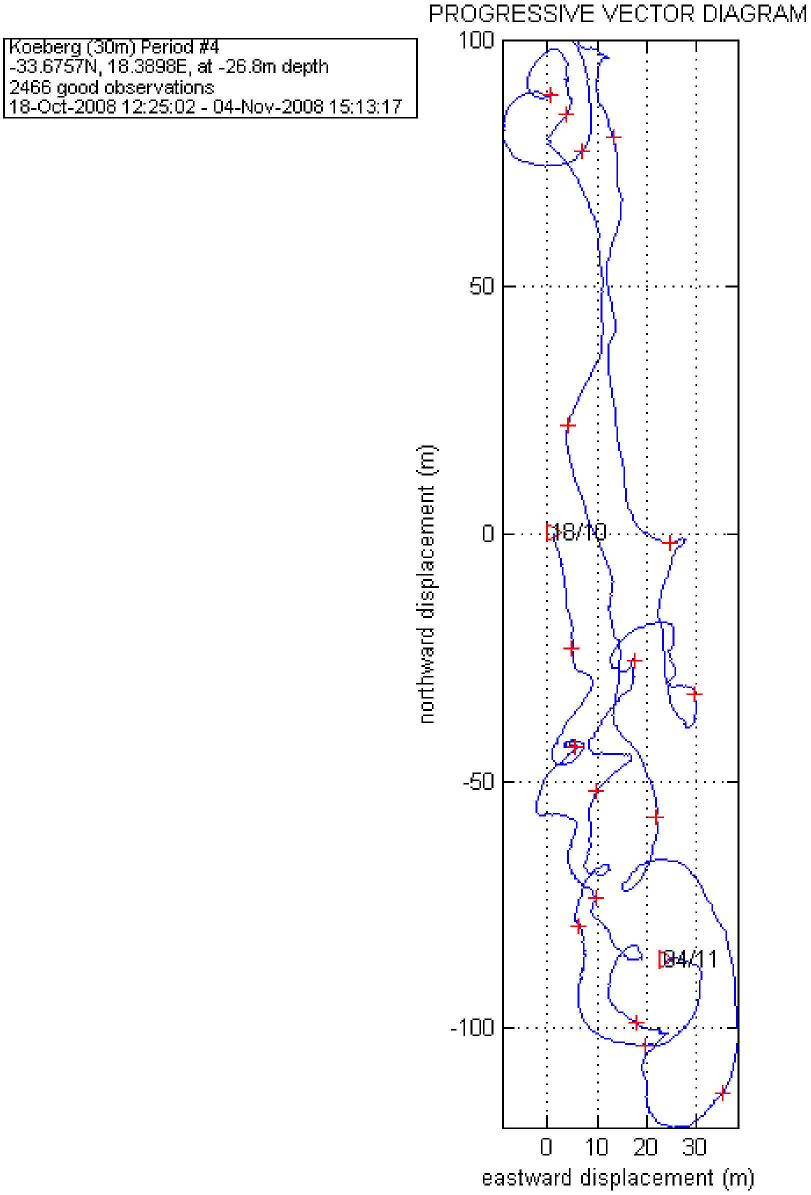


Figure 23: Progressive vector plot of current data at 26.8m.

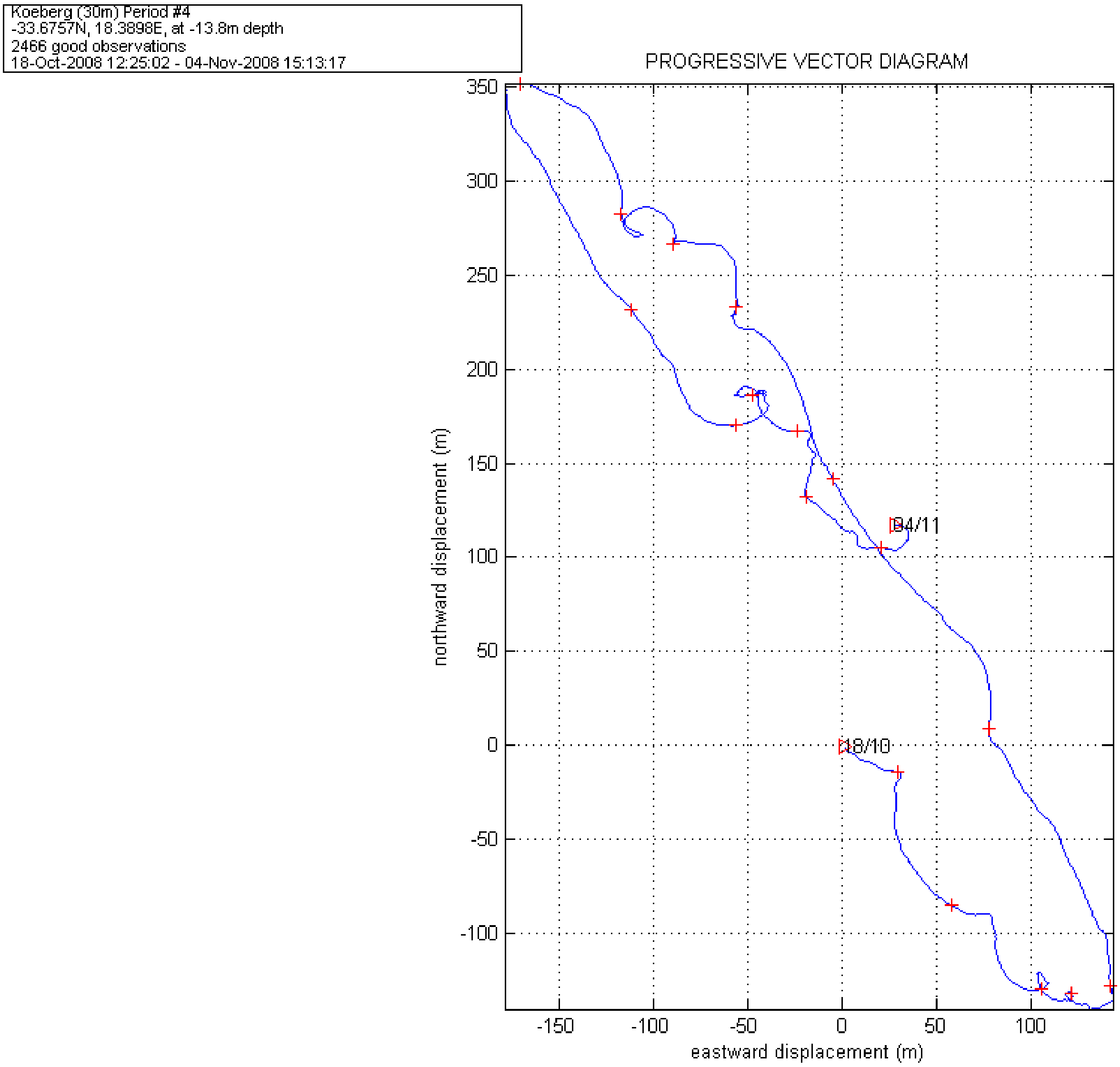


Figure 24: Progressive vector plot of current data at 13.8m.

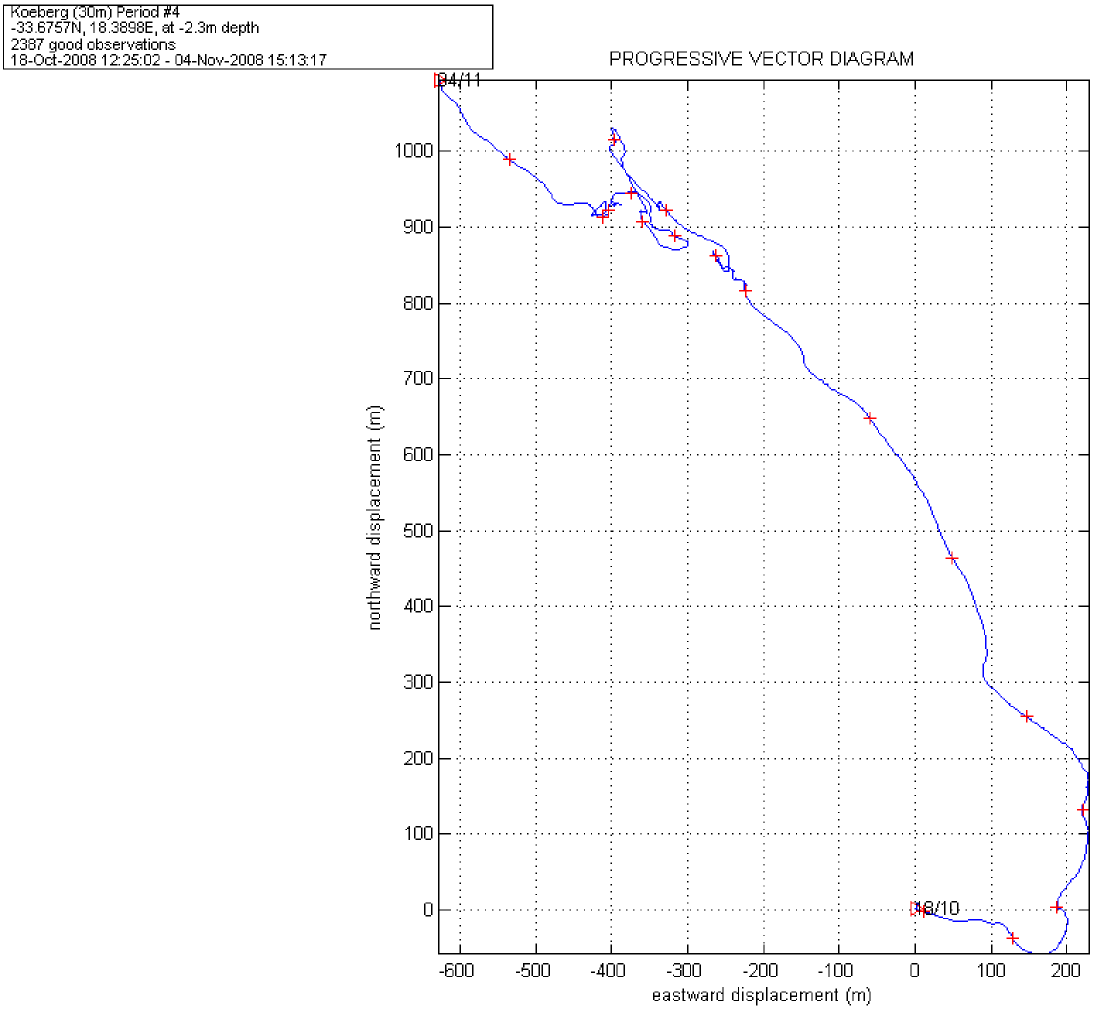


Figure 25: Progressive vector plot of current data at 2.3m.

5.2.2 Wave Data.

5.2.2.1 Hs and Tp summary plot

Figure 26 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.2.2.2 Hs and Dp summary plot

Figure 27 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.2.2.3 Tp and Dp summary plot

Figure 28 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

Koeberg (30m) Period #4
-33.6757N, 18.3898E, at 30m depth
411 good observations
18-Oct-2008 12:25:00 - 04-Nov-2008 14:25:00

JOINT DISTRIBUTION OF HS AND TP

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5																0.00
0.5-0.75					0.49	0.73	0.24									1.46
0.75-1			1.70	0.24	2.19	3.65	0.73									8.52
1-1.25				0.49	1.22	5.11	4.62	0.49								11.92
1.25-1.5			0.24	0.49	0.73	7.06	9.73	0.73	0.24							19.22
1.5-1.75				0.24	1.22	2.19	6.81	0.24								10.71
1.75-2						4.14	8.03	3.41	0.24							15.82
2-2.25						4.87	5.84	2.43								13.14
2.25-2.5						1.70	4.62	1.46								7.79
2.5-2.75						0.49	4.87	0.97								6.33
2.75-3						0.49	1.95	1.70								4.14
3-3.25							0.24									0.24
3.25-3.5							0.24	0.24								0.49
3.5-3.75								0.24								0.24
3.75-4																0.00
4-4.25																0.00
4.25-4.5																0.00
4.5-4.75																0.00
4.75-5																0.00
5-5.25																0.00
5.25-5.5																0.00
Σ	0.00	0.00	1.95	1.46	5.84	30.41	47.93	11.92	0.49	0.00	0.00	0.00	0.00	0.00	0.00	100.00

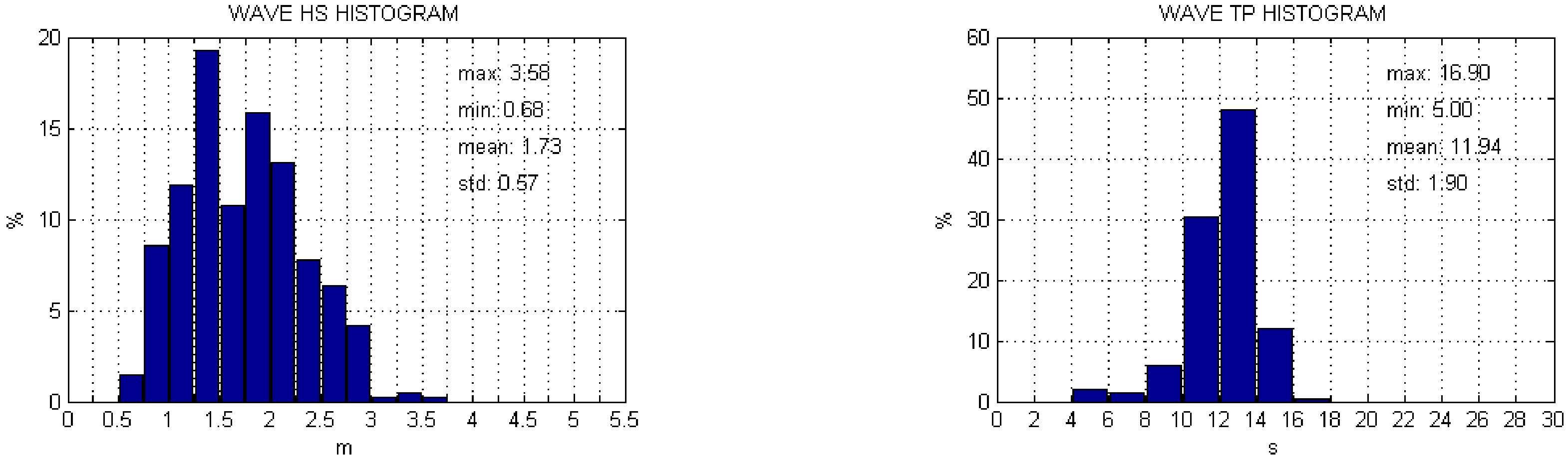
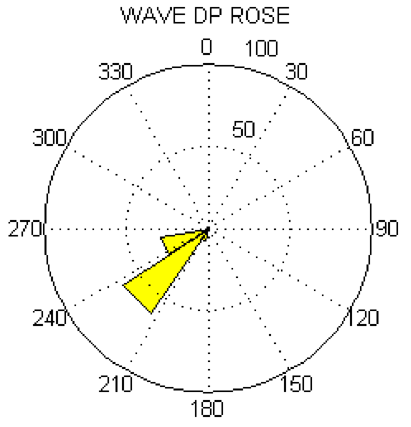


Figure 26: Summary plot of H_s and T_p.

Koeberg (30m) Period #4
-33.6757N, 18.3898E, at 30m depth
411 good observations
18-Oct-2008 12:25:00 - 04-Nov-2008 14:25:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5																	0.00
0.5-0.75										0.49	0.73	0.24					1.46
0.75-1										1.46	3.65	3.41					8.52
1-1.25										2.19	6.57	2.92	0.24				11.92
1.25-1.5	0.24								0.24	0.73	11.44	6.57					19.22
1.5-1.75										1.22	6.08	3.41					10.71
1.75-2										0.24	10.71	4.87					15.82
2-2.25										0.49	8.27	4.38					13.14
2.25-2.5											6.08	1.46	0.24				7.79
2.5-2.75										0.24	4.62	1.46					6.33
2.75-3										0.24	3.65	0.24					4.14
3-3.25											0.24						0.24
3.25-3.5											0.49						0.49
3.5-3.75											0.24						0.24
3.75-4																	0.00
4-4.25																	0.00
4.25-4.5																	0.00
4.5-4.75																	0.00
4.75-5																	0.00
5-5.25																	0.00
5.25-5.5																	0.00
Σ	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	7.30	62.77	28.95	0.49	0.00	0.00	0.00	100.00



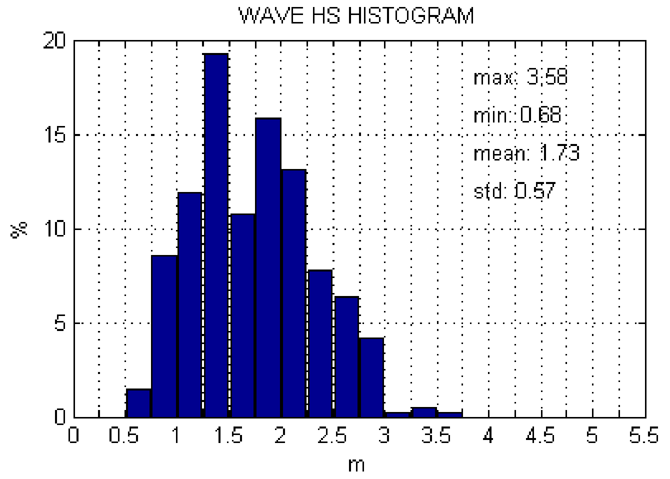
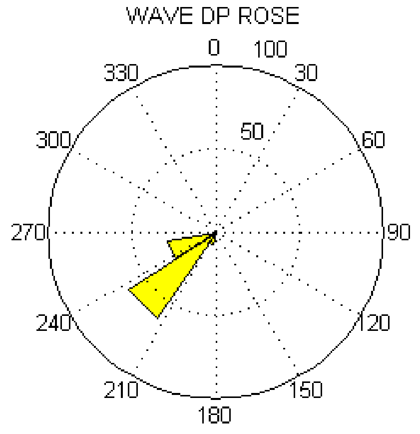


Figure 27: Summary plot of H_s and D_p.

Koeberg (30m) Period #4
-33.6757N, 18.3898E, at 30m depth
411 good observations
18-Oct-2008 12:25:00 - 04-Nov-2008 14:25:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4																	0.00
4-6										0.49	0.73	0.73					1.95
6-8										0.24	0.97	0.24					1.46
8-10										0.49	4.14	0.97	0.24				5.84
10-12	0.24								0.24	3.16	17.03	9.73					30.41
12-14										2.68	31.63	13.38	0.24				47.93
14-16										0.24	7.79	3.89					11.92
16-18											0.49						0.49
18-20																	0.00
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	7.30	62.77	28.95	0.49	0.00	0.00	0.00	100.00



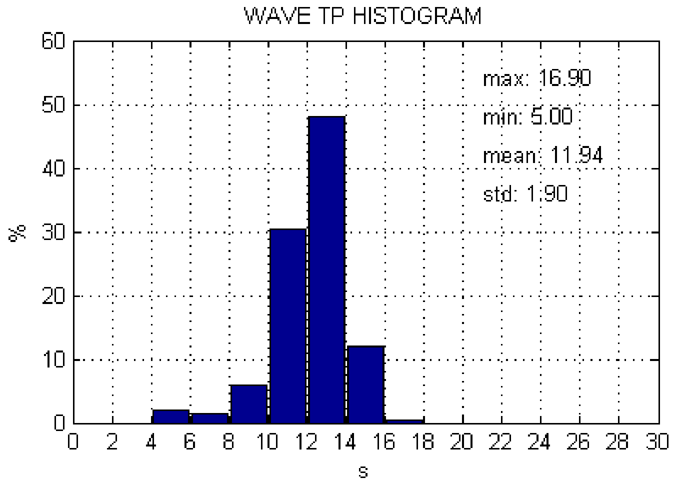


Figure 28: Summary plot of T_p and D_p.

5.2.2.4 Wave spectral plot

Figure 29 displays wave spectral plots for a significant wave event. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

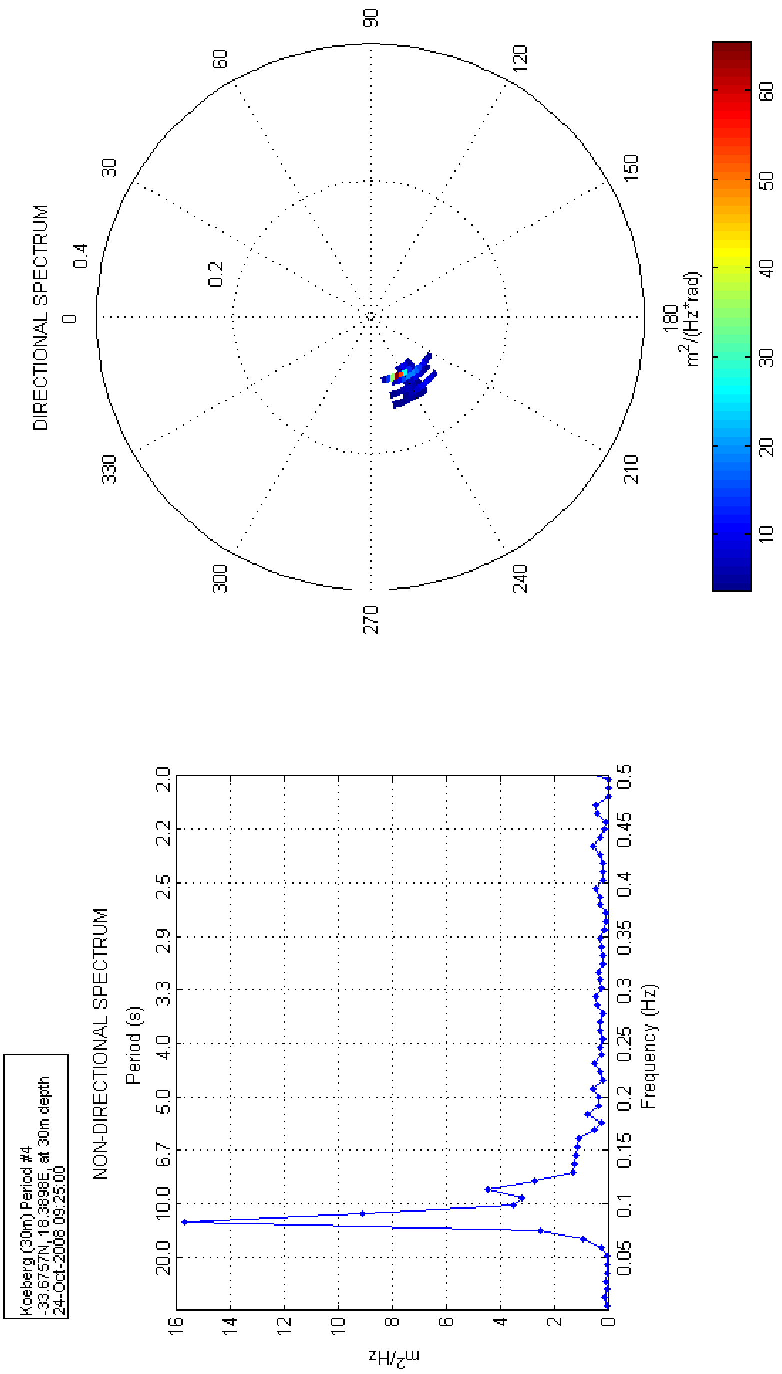


Figure 29: Wave spectra for 24th of October 2008 at 09:25:00.

5.3 COMPARISON PLOTS

5.3.1 Hs, Tp and Dp time series plots for 10m and 30m ADCPs.

Figure 30 displays a time series plot of the main wave parameters:

- The first (upper) panel is of the significant wave height (Hs).
- The second panel is of the peak period (Tp).
- The third panel is of the peak wave direction (Dp).

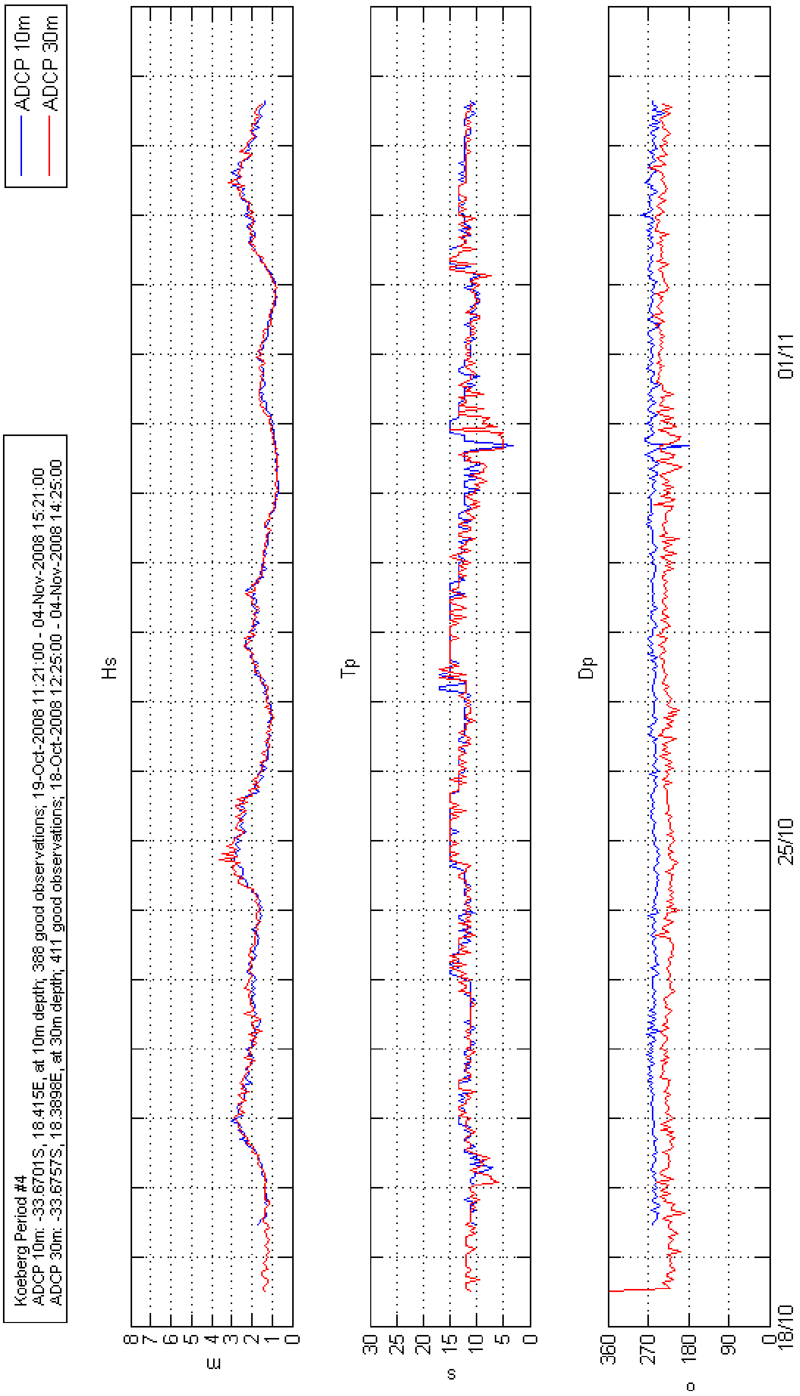


Figure 30: Wave Hs, Tp, and Dp for 10m and 30m ADCP.

5.3.2 Water properties: RBR-CT loggers, Thermister String and ADCPs temperature sensors.

Figure 31 displays a time series plot, which consists of:

- The first panel is of the observed water temperature from surface and bottom RBR loggers, as well as ADCP temperature sensor against time.
- The second panel is of the derived salinity from the two RBR loggers against time.

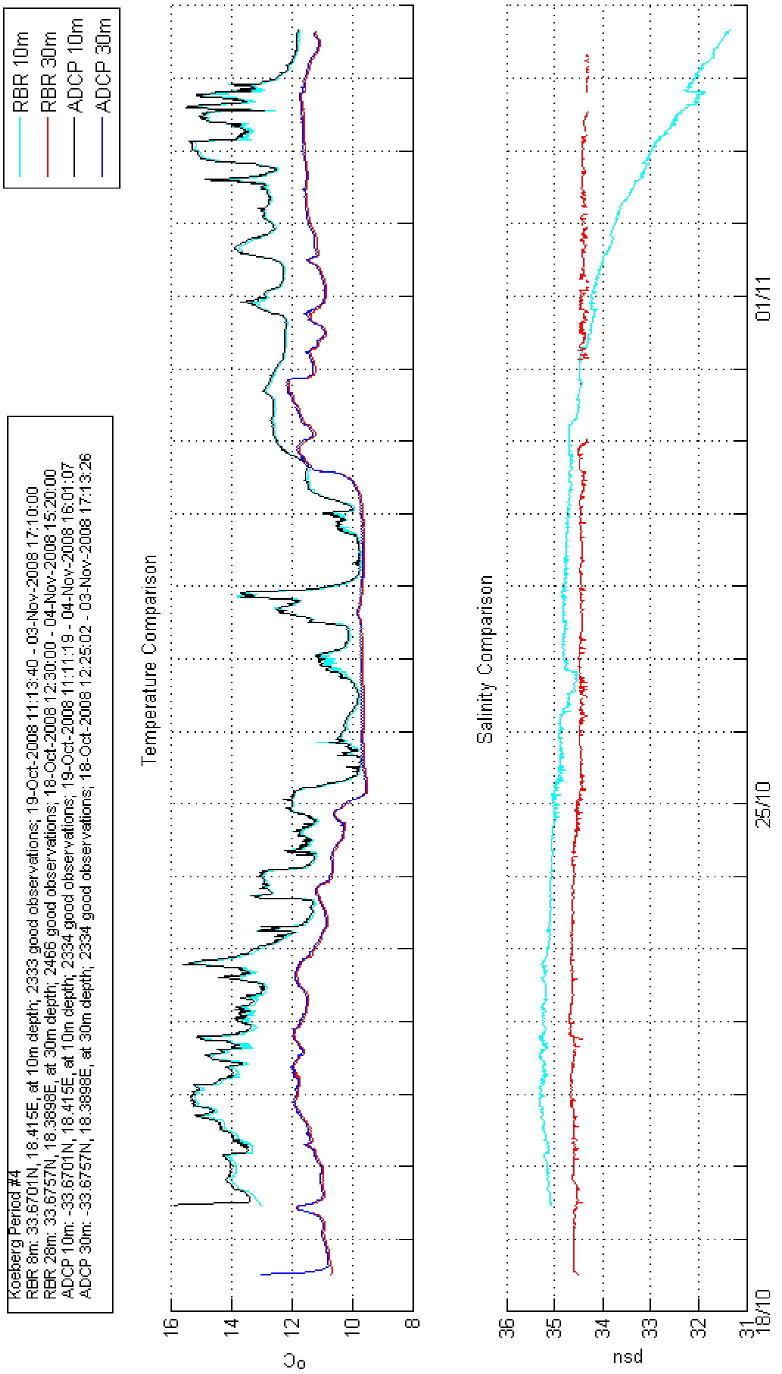


Figure 31: Time series of temperature and salinity from the RBR logger and ADCPs.

6. DISCUSSION

The fourth set of oceanographic data collected at Koeberg for the period between October 18th and November 4st 2008 has been presented in this report. The measurements taken fall within a larger dataset being compiled to assist a preliminary safety survey of multiple sites around the South African coast reports for Eskom.

At the Koeberg site, 2 600 kHz ADCPs and 2 RBR-CT loggers have been deployed to measure currents, waves and water temperature and salinity. The ADCPs are fixed on a frame at ~10m and ~30m. The RBR loggers are attached to the frame.

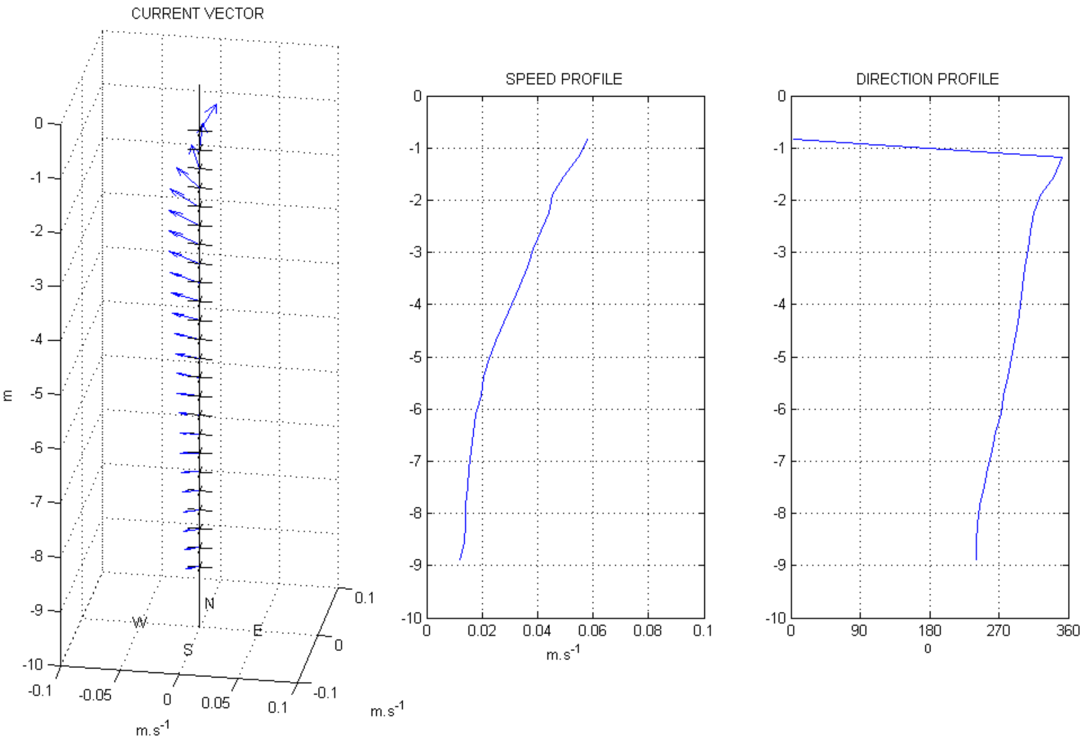


Figure 32: Mean profile plot for 10m ADCP.

The average surface current speed at the 10m site was ~0.16ms^{-1}, decreasing to ~0.08ms^{-1} at ~9m depth. The flow throughout the water column was variable. The mean current profile plot, presented in Figure 32, shows the gradual decrease in the vector mean speed.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.70m, with a wave period of 12.46s and mean direction to W/WSW.

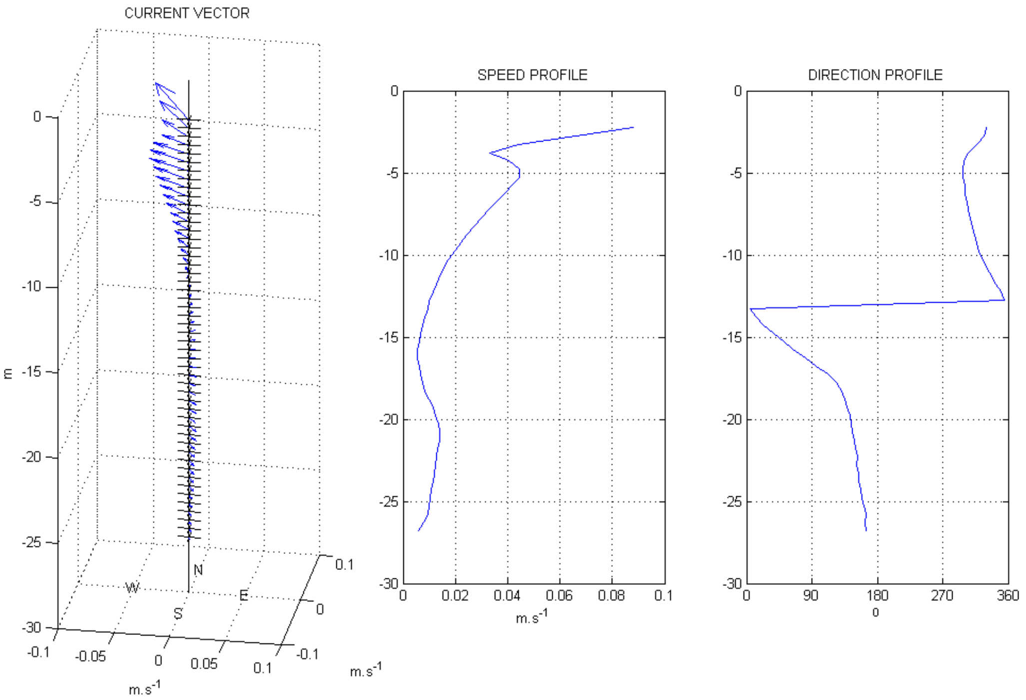


Figure 33: Mean profile plot for 30m ADCP.

The average surface current speed at the 30m site was ~0.18ms^{-1}, decreasing to ~0.06ms^{-1} at ~26.8m depth. The flow throughout the water column was variable. The mean current profile plot, presented in Figure 33, shows the gradual decrease in the vector mean speed.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.73m, with a wave period of 11.94s and mean direction to SW.

The temperature values recorded from the various independent instruments are in agreement with each other.

7. INSTRUMENT PARTICULARS FOR SERVICE VISIT FOUR

7.1 ADCP RECOVERY AND RE-DEPLOYMENT SHEETS

10m ADCP.

1. RECOVERY Site Name: Koeberg Date: 4 Nov 2008 .

Instrument type and serial number			RDI	11424
Recovery date and time	LT-x	GMT	4 Nov 2008 16:05	
Latitude **(do not ignore – if same, please indicate)**			33 40.206	
Longitude **(do not ignore – if same, please indicate)**			18 24.897	
Switch off date and time	LT-x	GMT	6 Nov 2008 18:08	
File size			168Mb	
Was the data copied to memory card?			Y-x	N

2. **RE-DEPLOYMENT Site Name: Koeberg 10m Date 8 Nov 2008**

Instrument type and serial number (do not ignore – if same, please indicate)			RDI	11424
Install a new battery and/or check the voltage				1 * 44.9
Frequency of unit being used			600kHz	
Depth range			10m	
Number of bins (calculated automatically)			42	
Bin Size (calculated automatically)			0.35	
Wave burst duration			41	
Time between wave bursts			60min	
Pings per ensemble			500	
Ensemble interval			10min	
Deployment duration			14days	
Transducer depth			10m	
Any other commands			Min TP,RI0	
Temperature			5	
Recorder size			1 * 1GBytes + 128MBytes	

Consequences of the sampling parameters

First and last bin range			1.41	15.76
Battery usage				440Wh
Standard deviation				1.08
Storage space required				133MB
Set the ADCP clock	LT-x	GMT	06H24	
Run pre-deployment tests				
Name the ADCP deployment			Dpl10	

Deployment details

Switch on date and time	LT-x	GMT	8 Nov 2008 06h24
Deployment date and time	LT-x	GMT	8 Nov 2008 10h350
Deployment Latitude **(do not ignore – if same, please indicate)**			33 40.206
Deployment Longitude **(do not ignore – if same, please indicate)**			18 24.897

Site depth	10m	Deployment depth	**10m**
Acoustic release (1) serial number and release code		**-**	**-**
Acoustic release (2) serial number and release code			**-**
Argos beacon serial number		**-**	
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)		**11424_08112008_Koeb 10m**	

30m ADCP.

1. RECOVERY Site Name: Koeberg Date: 4 Nov 2008 .

Instrument type and serial number		RDI	10119
Recovery date and time	LT-x	GMT	**4 Nov 2008 15:25**
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Switch off date and time	LT-x	GMT	5 Nov 2008 04:20
File size			145Mb
Was the data copied to memory card?		Y-x	N

2. **RE-DEPLOYMENT Site Name: Koeberg 30m Date 8 Nov 2008**

Instrument type and serial number (do not ignore – if same, please indicate)		RDI	**10119**
Install a new battery and/or check the voltage			**1 * 44.9**
Frequency of unit being used	**600kHz**		
Depth range	**30m**		
Number of bins (calculated automatically)	**69**		
Bin Size (calculated automatically)	**0.5**		
Wave burst duration	**34**		
Time between wave bursts	**60min**		
Pings per ensemble	**250**		
Ensemble interval	**10min**		
Deployment duration	**14days**		
Transducer depth	**30m**		
Any other commands	**Min TP,RI0**		
Temperature	**5**		
Recorder size	**2 * 1GBytes**		

Consequences of the sampling parameters

First and last bin range		**1.6**	**35.6**
Battery usage			**447Wh**
Standard deviation			**0.86**
Storage space required			**112.5**
Set the ADCP clock	LT-x	GMT	**06h14**
Run pre-deployment tests			
Name the ADCP deployment	**Dpl30**		

Deployment details

Switch on date and time	LT-x	GMT	**8 Nov 2008 06h10**
Deployment date and time	LT-x	GMT	**8 Nov 2008 10:03**

Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Site depth	30m	Deployment depth	**30m**
Acoustic release (1) serial number and release code		**Cart**	**32385**
Acoustic release (2) serial number and release code			
Argos beacon serial number			
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**10119_K30m_08112008_Koeb30m**

7.2 RBR-CT LOGGERS RECOVERY AND RE-DEPLOYMENT SHEETS

1. **RECOVERY** **Site Name: : Koeberg** **Date 4 Nov 2008**

Instrument type and serial number			RBR	12995
Recovery date and time	LT	GMT	**4 Nov 2008 16:05**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LT	GMT	6 Nov 2008 20:07:54	
File size			3kB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			12995_06112008_2007	

2. **RE-DEPLOYMENT** **Site Name: Koeberg 10m** **Date: 8 Nov 2008**

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12995
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period		**10 min**
Averaging period		**1 min**
Expected deployment duration		**3 weeks**
Start of logging (date / time)	8 Nov 2008	06h36:30
End of logging (date / time)	15 Dec 2008	12h00
Memory usage		.4%
Battery usage		978mAH

Deployment details

Deployment date and time	LT	GMT	8 Nov 2008 10h35	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Site name			Koeberg 10m	
Site depth			10m	
Deployment depth			10m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	

Save *log* file (filename format: ***serialnumber_date***)	**12995 and 12997_08112008_Koeb10m and 30m_ RBRLogs**

1. RECOVERY Site Name: : Koeberg Date 4 Nov 2008

Instrument type and serial number			RBR	12997
Recovery date and time	LT	GMT	**4 Nov 2008 15:25**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**	
Switch off date and time	LT	GMT	6 Nov 2008 20:04:44	
File size			3kB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			12977_06112008_2004	

2. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 8 Nov 2008

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12997
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	8 Nov 2008	06h40:00
End of logging (date / time)	15 Dec 2008	12h00
Memory usage		.4%
Battery usage		997mAH

Deployment details

Deployment date and time	LT - x	GMT	8 Nov 2008 10h03	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.397**	
Site name			Koeberg 30m	
Site depth			30m	
Deployment depth			30m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			**12995 and 12997_08112008_Koeb10m and 30m_ RBRLogs**	

7.3 ADCP CONFIGURATION FILES

10m ADCP.

```
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 336.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1128
;Saved Screen        = 3
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 124.91 MB (130974144 bytes)
;Power usage         = 410.91 Wh
;Battery usage       = 0.9
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
;
```

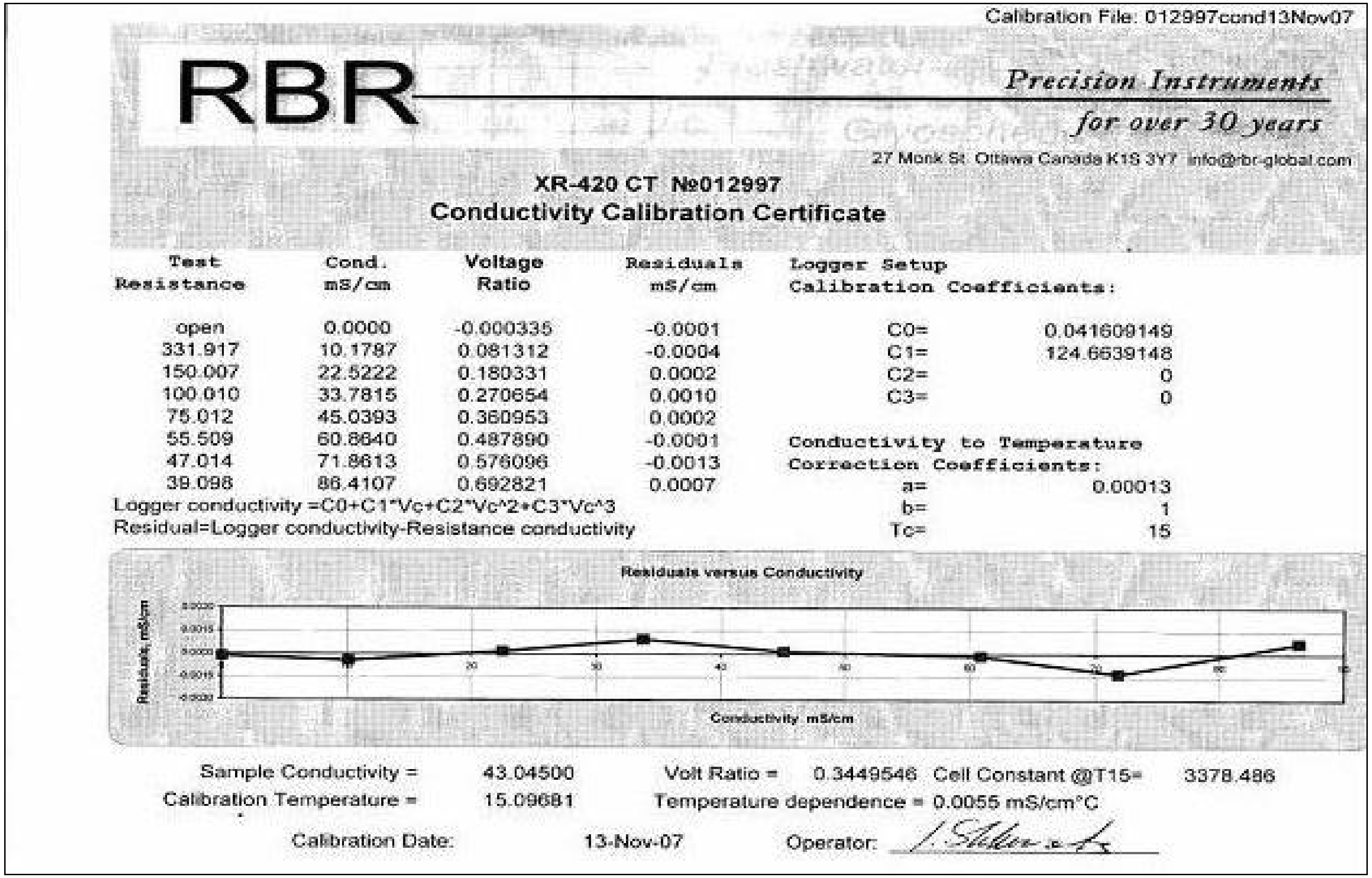
```
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

30m ADCP.

```
CR1
CF11101
EA0
EB0
ED300
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN69
WP250
WS50
WV175
HD111000000
HB5
HP4080
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 360.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 2000
;Saved Screen        = 2
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.60 m
;Last cell range     = 35.60 m
;Max range           = 38.22 m
;Standard deviation = 0.86 cm/s
;Ensemble size       = 1534 bytes
;Storage required    = 112.45 MB (117908640 bytes)
```

```
;Power usage        = 447.68 Wh
;Battery usage      = 1.0
;Samples / Wv Burst = 4080
;Min NonDir Wave Per= 2.59 s
;Min Dir Wave Period= 4.31 s
;Bytes / Wave Burst = 318320
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

7.4 RBR-CT CALIBRATION CERTIFICATES



Calibration File: 012997cond13Nov07

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012997
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000335	-0.0001
331.917	10.1787	0.081312	-0.0004
150.007	22.5222	0.180331	0.0002
100.010	33.7815	0.270654	0.0010
75.012	45.0393	0.360953	0.0002
55.509	60.8640	0.487890	-0.0001
47.014	71.8613	0.576096	-0.0013
39.098	86.4107	0.692821	0.0007

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

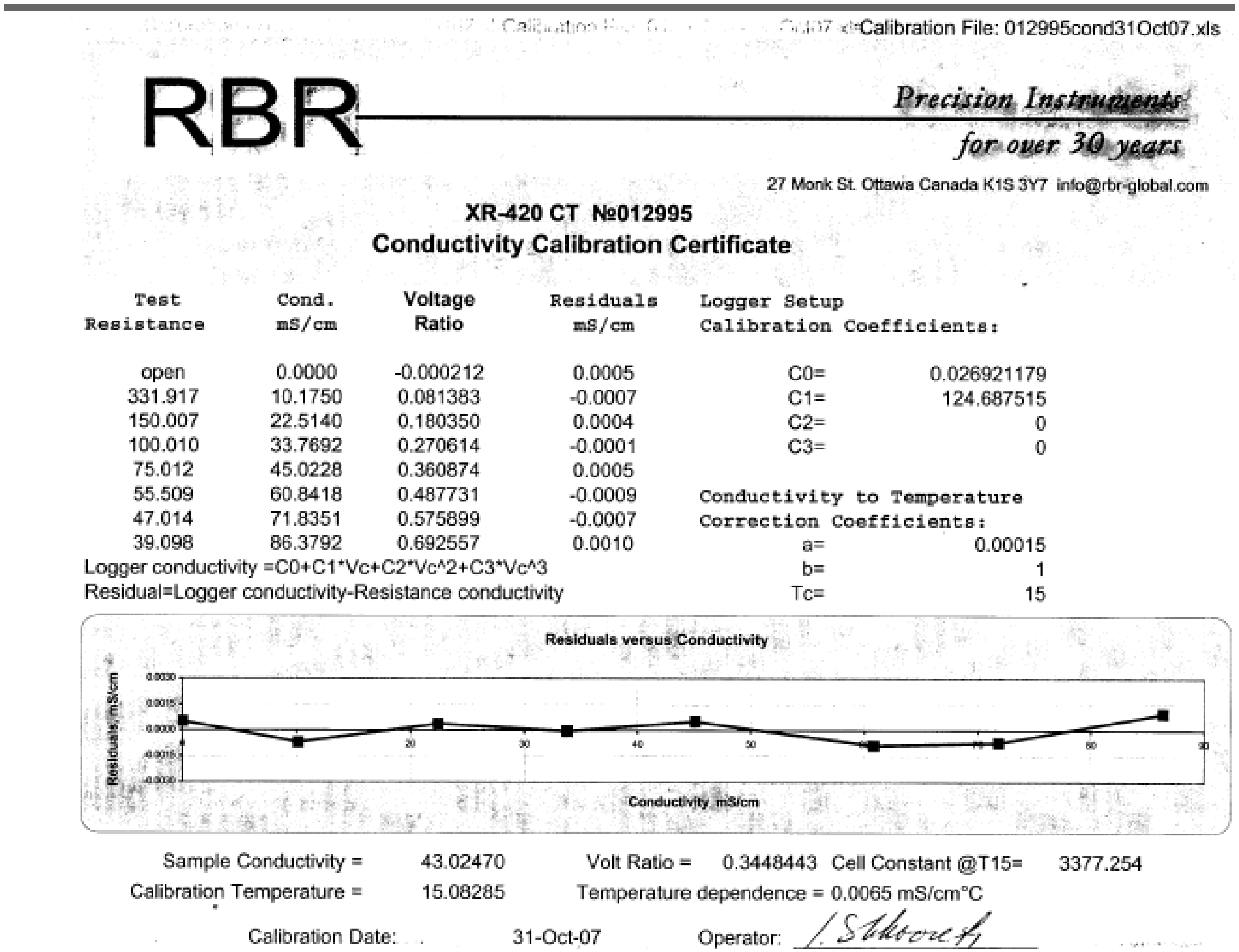
C0= 0.041609149
C1= 124.6639148
C2= 0
C3= 0

Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 43.04500
Calibration Temperature = 15.09681
Volt Ratio = 0.3449546
Cell Constant @T15= 3378.486
Temperature dependence = 0.0055 mS/cm°C
Calibration Date: 13-Nov-07
Operator:



Calibration File: 012995cond31Oct07.xls

RBR

Precision Instruments

for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012995

Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000212	0.0005
331.917	10.1750	0.081383	-0.0007
150.007	22.5140	0.180350	0.0004
100.010	33.7692	0.270614	-0.0001
75.012	45.0228	0.360874	0.0005
55.509	60.8418	0.487731	-0.0009
47.014	71.8351	0.575899	-0.0007
39.098	86.3792	0.692557	0.0010

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3

Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.026921179
C1= 124.687515
C2= 0
C3= 0

Conductivity to Temperature
Correction Coefficients:

a= 0.00015
b= 1
Tc= 15

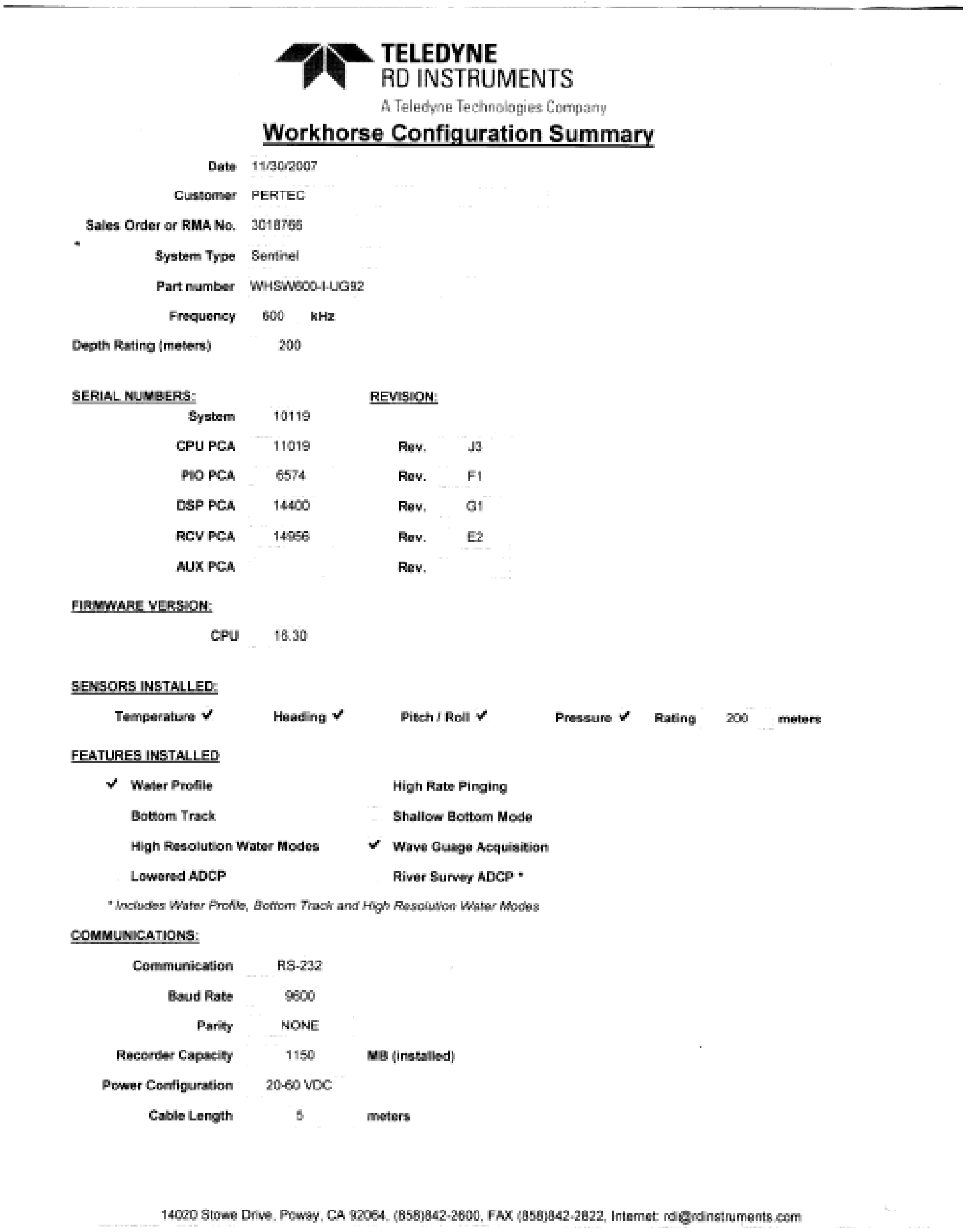
Residuals versus Conductivity

Sample Conductivity = 43.02470
Volt Ratio = 0.3448443
Cell Constant @T15= 3377.254
Calibration Temperature = 15.08285
Temperature dependence = 0.0065 mS/cm°C

Calibration Date: 31-Oct-07

Operator: [illegible]

7.5 TRDI ADCP CALIBRATION CERTIFICATE



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date	11/30/2007
Customer	PERTEC
Sales Order or RMA No.	3018766
System Type	Sentinel
Part number	WHSW600-I-UG92
Frequency	600 kHz
Depth Rating (meters)	200

SERIAL NUMBERS: **REVISION:**

System	10119		
CPU PCA	11019	Rev.	J3
PIO PCA	6574	Rev.	F1
DSP PCA	14400	Rev.	G1
RCV PCA	14956	Rev.	E2
AUX PCA		Rev.	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ Heading ✓ Pitch / Roll ✓ Pressure ✓ Rating 200 meters

FEATURES INSTALLED

✓ Water Profile
Bottom Track
High Resolution Water Modes
Lowered ADCP

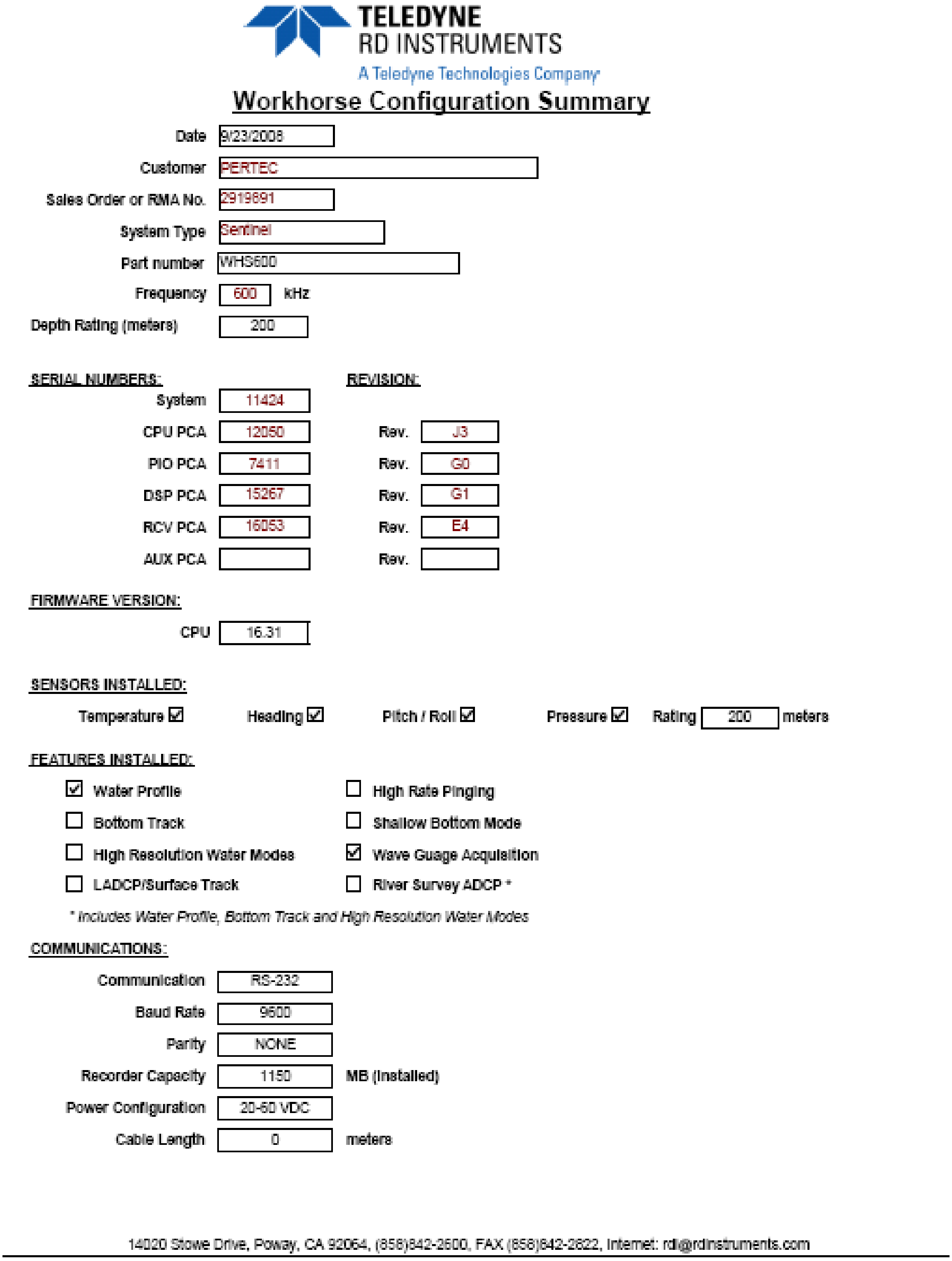
High Rate Pinging
Shallow Bottom Mode
✓ Wave Guage Acquisition
River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication	RS-232
Baud Rate	9600
Parity	NONE
Recorder Capacity	1150 MB (installed)
Power Configuration	20-60 VDC
Cable Length	5 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 9/23/2008
Customer PERTEC
Sales Order or RMA No. 2919691
System Type Sentinel
Part number WHS600
Frequency 600 kHz
Depth Rating (meters) 200

SERIAL NUMBERS:		REVISION:	
System	11424		
CPU PCA	12050	Rev.	J3
PIO PCA	7411	Rev.	G0
DSP PCA	15267	Rev.	G1
RCV PCA	16053	Rev.	E4
AUX PCA		Rev.	

FIRMWARE VERSION:

CPU 16.31

SENSORS INSTALLED:

Temperature ☑ Heading ☑ Pitch / Roll ☑ Pressure ☑ Rating 200 meters

FEATURES INSTALLED:

☑ Water Profile
☐ Bottom Track
☐ High Resolution Water Modes
☐ LADCP/Surface Track
☐ High Rate Pinging
☐ Shallow Bottom Mode
☑ Wave Guage Acquisition
☐ River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232
Baud Rate 9600
Parity NONE
Recorder Capacity 1150 MB (installed)
Power Configuration 20-60 VDC
Cable Length 0 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2622, Internet: rdi@rdinstruments.com

LWANDLE TECHNOLOGIES (PTY) LTD

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT FIVE

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

4 February 2009

Job No: LT-JOB-50

Directors: C.P. Matthysen, M. Majodina, B.J. Spolander

LWANDLE TECHNOLOGIES (PTY) LTD
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Co Reg. No. 2003/015524/07

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1. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 5 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary for 10m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-8.7	99.93	0.8300	0.0955	0.1095	0.0575	3.38
-8.2	99.93	0.8562	0.1006	0.1145	0.0626	3.59
-7.7	99.90	0.8651	0.1050	0.1181	0.0670	3.25
-7.2	99.90	0.8854	0.1087	0.1212	0.0715	2.47
-6.7	99.90	0.8961	0.1131	0.1241	0.0758	1.19
-6.2	99.90	0.9067	0.1179	0.1275	0.0809	359.80
-5.7	99.93	0.9377	0.1206	0.1251	0.0849	0.24
-5.2	99.97	0.9468	0.1255	0.1298	0.0890	356.68
-4.7	99.97	0.9402	0.1327	0.1384	0.0961	352.53
-4.2	99.97	0.9395	0.1388	0.1417	0.1023	350.4
-3.7	99.97	0.9621	0.1453	0.1450	0.1091	348.45
-3.2	99.97	0.9640	0.1534	0.1476	0.1166	348.03
-2.7	99.87	0.9707	0.1631	0.1516	0.1264	347.65
-2.2	99.93	0.9678	0.1736	0.1553	0.1369	347.47
-1.7	99.87	0.9615	0.1867	0.1595	0.1502	346.98
-1.2	96.22	1.0180	0.2045	0.1664	0.1647	343.99

Table 2 – Waves summary for 10m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	98.81	3.98	0.59	1.43	0.57
Tp (s)	98.81	19.50	4.80	11.69	2.17
Dp (°)	98.81	284.75	201.75	241.86	8.75

Table 3 – Current flow summary for 30m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-26.9	100.00	0.3572	0.0646	0.0478	0.0315	14.57
-26.5	100.00	0.3705	0.0674	0.0491	0.0327	13.43
-26.2	100.00	0.3821	0.0691	0.0502	0.0333	13.71
-25.8	100.00	0.3679	0.0713	0.0510	0.0338	13.32
-25.5	100.00	0.3906	0.0734	0.0523	0.0344	13.13
-25.1	100.00	0.3783	0.0755	0.0526	0.0351	12.87
-24.8	100.00	0.3942	0.0775	0.0536	0.0354	12.25
-24.4	100.00	0.3842	0.0792	0.0546	0.0364	11.98
-24.1	100.00	0.3827	0.0816	0.0553	0.0365	11.48
-23.7	100.00	0.3832	0.0836	0.0562	0.0372	11.09
-23.4	100.00	0.3944	0.0850	0.0566	0.0381	10.83
-23.0	100.00	0.4143	0.0868	0.0576	0.0390	9.56
-22.7	99.97	0.3911	0.0886	0.0581	0.0401	8.95
-22.3	100.00	0.3884	0.0904	0.0588	0.0408	7.99
-22.0	100.00	0.3990	0.0919	0.0596	0.0414	6.82
-21.6	100.00	0.3901	0.0932	0.0599	0.0419	6.11
-21.3	100.00	0.3974	0.0944	0.0607	0.0428	4.47
-20.9	100.00	0.4044	0.0958	0.0614	0.0439	3.30
-20.6	100.00	0.4019	0.0972	0.0621	0.0450	2.19
-20.2	100.00	0.3991	0.0983	0.0625	0.0460	0.97
-19.9	100.00	0.3988	0.0994	0.0631	0.0473	359.31
-19.5	100.00	0.4017	0.1008	0.0645	0.0494	357.77
-19.2	100.00	0.4034	0.1017	0.0652	0.0513	356.44
-18.8	99.97	0.4193	0.1026	0.0659	0.0534	354.96
-18.5	100.00	0.3997	0.1034	0.0667	0.0555	353.93
-18.1	100.00	0.4029	0.1047	0.0675	0.0575	352.83
-17.8	100.00	0.4012	0.1053	0.0684	0.0595	351.55
-17.4	100.00	0.4041	0.1071	0.0691	0.0623	350.62
-17.1	100.00	0.4032	0.1079	0.0698	0.0645	349.37
-16.7	100.00	0.4043	0.1094	0.0705	0.0673	348.45
-16.4	100.00	0.413	0.1107	0.0714	0.0694	347.33
-16.0	100.00	0.4324	0.1114	0.0725	0.0718	346.67
-15.7	100.00	0.4213	0.1128	0.0728	0.0739	345.32
-15.3	99.97	0.4181	0.1141	0.0741	0.0760	344.60
-15.0	100.00	0.407	0.1148	0.0749	0.0781	343.97
-14.6	100.00	0.4157	0.1162	0.0754	0.0799	342.89
-14.3	100.00	0.4228	0.1179	0.0763	0.0824	342.01
-13.9	100.00	0.4373	0.1184	0.0773	0.0838	341.27
-13.6	100.00	0.4372	0.1193	0.0778	0.0859	339.81
-13.2	100.00	0.4071	0.1214	0.0793	0.0891	337.24
-12.9	98.99	0.4235	0.1226	0.0736	0.0825	322.26

Table 4 – Waves summary for 30m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	99.25	2.86	0.54	1.35	0.50
Tp (s)	99.25	19.60	5.00	11.49	2.23
Dp (^{o})	99.25	258.75	149.75	237.81	12.47

Table 5 – Water temperature and salinity summary for 10m RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100.00	10.55	13.62	9.41
Conductivity	100.00	38.21	41.56	36.09
Salinity (psu)	100.00	34.58	35.14	33.48

Table 6 – Water temperature and salinity summary for 30m RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100.00	9.79	11.15	9.23
Conductivity	100.00	37.39	39.18	34.50
Salinity (psu)	99.01	34.50	34.99	33.03

1.1 DATA RETURN FOR KOEBERG SITE.

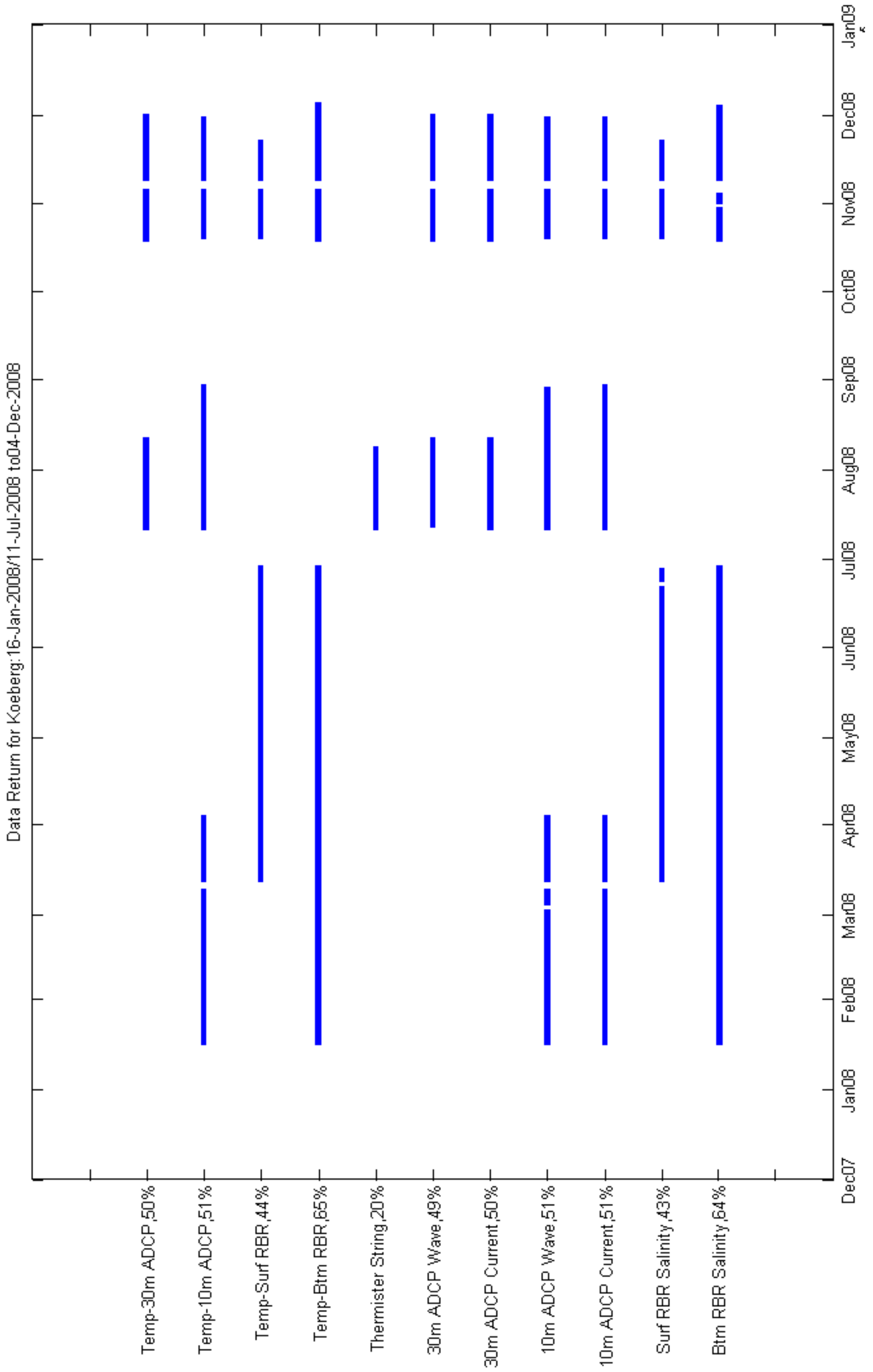


Figure 1: An indication of the data return (%) at the Koeberg site since the beginning of the project (Jan 16th 2008; July 11th 2008 for 30m ADCP and Thermister String). A break down of the temperature (Temp) return from all available instruments is given in the top 5 bars.

2. INTRODUCTION

2.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period November 8th 2008 - December 4th 2008 (Period 5). Recovery of the instruments was undertaken on December 4th and the redeployment on the 6th.

2.2 EQUIPMENT LIST

Lwandle provided the equipment as listed in Table 7 for the Koeberg site.

Table 7 – List of equipment provided.

Item	Operational (on site)	Spare (for whole project)
TRDI 600kHz ADCP	2	1
RBR XR420 CT logger	2	1
RBR Thermister String	0	0

2.3 MEASUREMENT LOCATION

The deployment locations of the moorings are recorded in Table 8.

Table 8 – Initial deployment locations.

Instrument	Latitude (^{o}S)	Longitude (^{o}E)
10m ADCP and RBR logger.	33.6701	18.4150
30m ADCP and RBR logger.	33.6757	18.3898

Table 9 – Water samples collected on December 6th 2008.

STN #	Lat	Long	SAMPLES type (W,B,G)	Exact Time HH:MM:SS	COMMENTS (if RBR profile is taken etc..)
30m	33 40.540	18 23.387	4m W	08:52	
30m	33 40.540	18 23.387	12m W	08:55	
30m	33 40.540	18 23.387	20m W	08:58	
30m	33 40.540	18 23.387	28m W	09:06	
10m	33 40.206	18 24.897	4m W	10:03	
10m	33 40.206	18 24.897	8m W	10:05	
1	33 40.127	18 24.902	4m W	10:08	
2	33 40.111	18 24.912	4m W	10:09	
3	33 40.098	18 24.912	4m W	10:11	
4	33 40.086	18 24.911	4m W	10:12	
5	33 40.070	18.24.918	4m W	10:14	

3. OPERATIONS

3.1 SUMMARY OF EVENTS.

December 4th 2008.
Recovery of the 10m and 30m ADCPs as well as the RBR-CT loggers that was attached on the respective frames was undertaken.

December 6th 2008.
Redeployment of all the instruments was successful. The 10m ADCP s/n 11424 was replaced with s/n 10841.

An unfortunate mix-up occurred in the field during the redeployment of the ADCPs on November 8th 2008 (SV4). The unit configured for the 10m site was deployed at 30m and the one configured for the 30m site was deployed at 10m.

3.2 INSTRUMENT CONFIGURATIONS

The deployed instrumentation configurations are given in this section and completed deployment / recovery sheets are given as an appendix (Section 7, page 53) to this report.

3.2.1 600kHz ADCP

Table 10 – Instrument configuration for the 10m ADCP.

Parameter	**Configuration**
ADCP model	600KHz WH ADCP
ADCP serial number	11424
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.35 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

The 10m ADCP was withdrawn and replaced with another one (s/n 10841).

Table 11 – Instrument configuration for the 30m ADCP.

Parameter	**Configuration**
ADCP model	600KHz WH ADCP
ADCP serial number	10119
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.5 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

3.2.2 RBR XR420 CT LOGGER

Table 12 – Instrument configuration for T&C Mooring Line.

Parameter	**Configuration**
XR 420 Temperature and Conductivity	s/n 12995 (10m) and s/n 12997 (30m)
Sampling and Averaging	Sample at 1Hz for 1 minute every 10 minutes

3.2.3 Biofouling Mooring

Table 13 – Instrument configuration for Biofouling Mooring Line.

Parameter	Configuration
Biofouling Plates	3 plates (20cmx20cm) at 3m and 3 plates (20cmx20cm) at 8m
Edgetech Acoustic Release	s/n 32385 release code 642102

3.3 RECOVER AND REDEPLOYMENT METHODOLOGY

3.3.1 T&C mooring and Thermister string

The T&C mooring line was deployed by lowering the array down via a rope through the anchor weights. The mooring line is recovered using divers to undo a single shackle that connects the mooring line to the anchor weights. Divers reattach the line onto the weights, after the instruments have been serviced.

The Thermister string is attached to the 30m ADCP frame. The string comprises of four nodes at 30m, 29m, 19m, and 9m below the surface.

3.3.2 ADCP mooring

The ADCP Frame is lowered to the bottom and moved into position by divers, who also attach chain sections that act as anchors. To retrieve the frame divers have to locate the mooring, take off the anchor chains and surface the frame using air lift bags that they attach.

Figure 2 – ADCP frame with 600KHz instrument.

3.3.3 Biofouling mooring

The biofouling mooring line was deployed by lowering the array down via a rope through the anchor weights. Divers would locate the mooring line and retrieve a surface and bottom plate from the line at the required sampling periods.

4. DATA QUALITY CONTROL

4.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

4.1.1 Current processing

- The record was truncated to exclude times pre and post deployment.
- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 15’ W (both ADCP sites).
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP’s pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of 0.2ms^{-1} was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined.
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

4.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 15’ W (both ADCP sites).
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

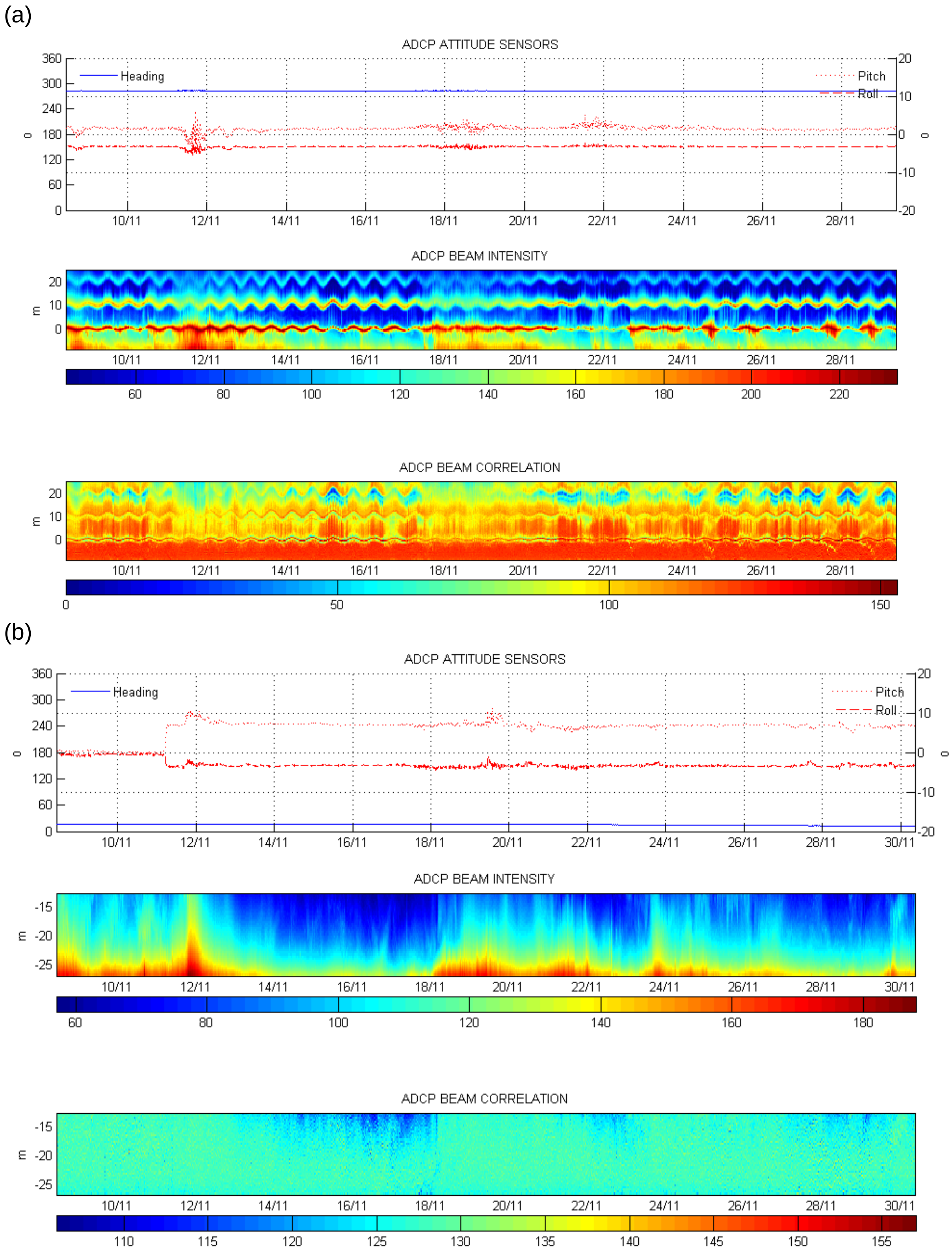


Figure 3: Quality control data from the (a) 10m and (b) 30m ADCPs. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

4.2 RBR-CT LOGGER AND THERMISTER STRING

The conductivity (from the CT-logger) and temperature data were exported directly from the RBR software into Matlab for further processing.

- The record was truncated to exclude times pre and post deployment.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.
- Salinity less than 33 psu were discarded for the 30m unit.

4.3 BIOFOULING.

The following standard procedure is normally followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates are measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 CaC03 chips are added.
- Sample bottles are stored upright in the dark.

Recovery of the biofouling plates was not scheduled.

4.4 WATER SAMPLE.

Water samples were collected and sent to the CSIR for analysis.

5. DATA PRESENTATION

All data presented have been subject to the quality control procedures detailed in the previous section. Bad data have been excluded from all plots and calculations.

All plots in this section include a stamp that details the location, depth, time period and number of observations that the plot is based upon. Wherever possible, scaling of parameters has been kept constant throughout this section to facilitate comparison between plots and stations.

5.1 10M ADCP

5.1.1 Current Data

5.1.1.1 Time series plot

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

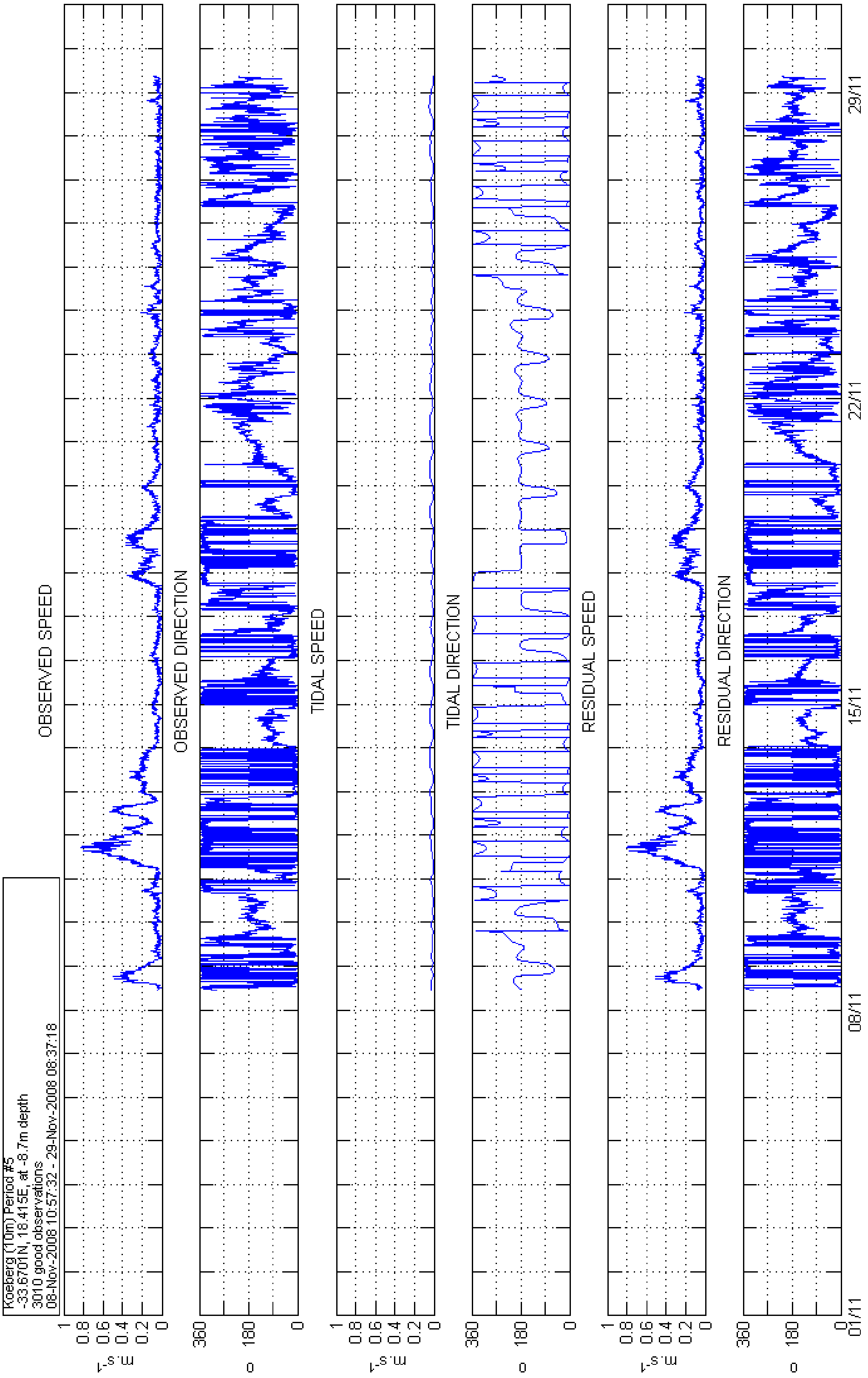


Figure 4: Time series plot of the 10m ADCP's current data at 8.7m.

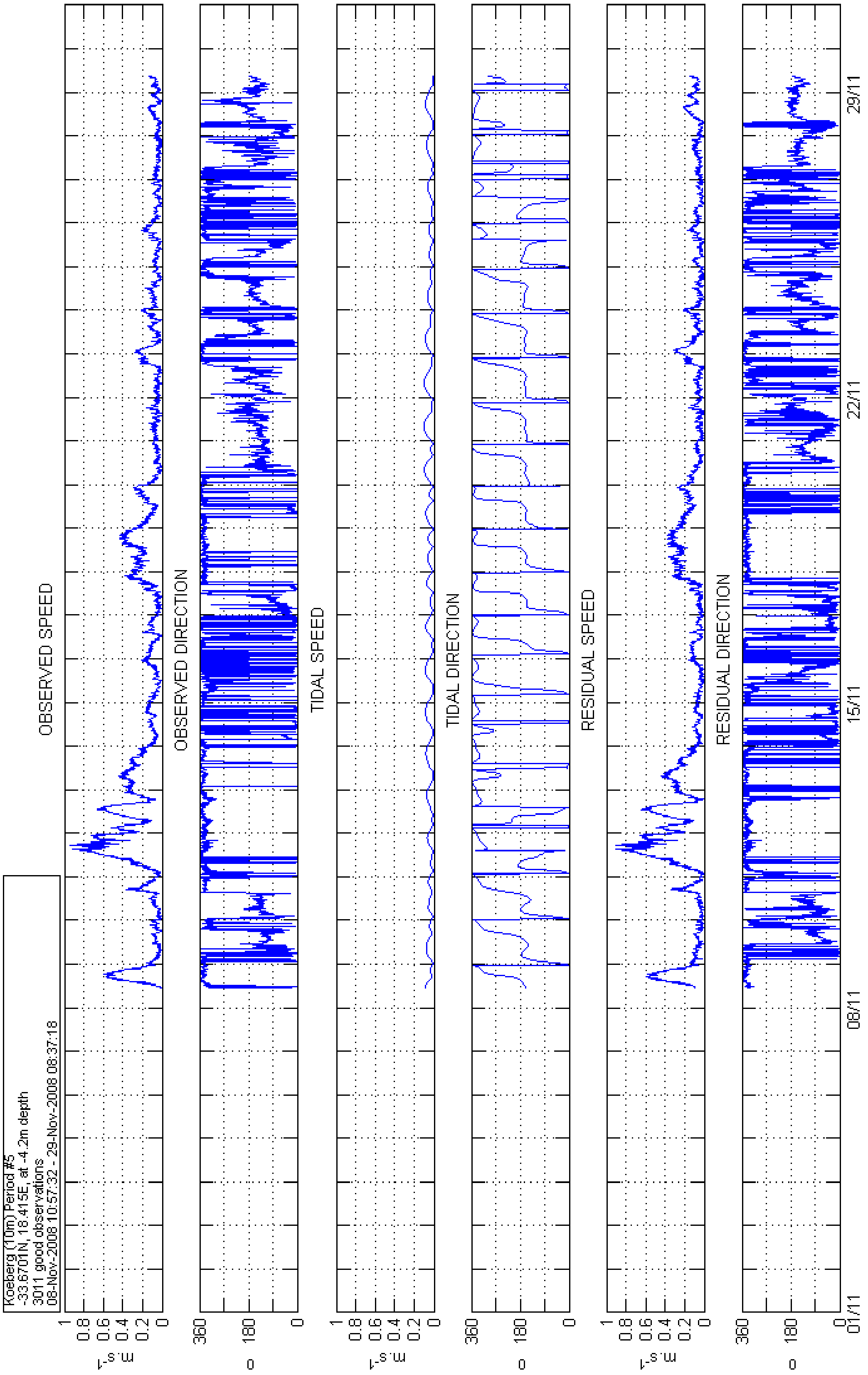


Figure 5: Time series plot of the 10m ADCP's current data at 4.2m.

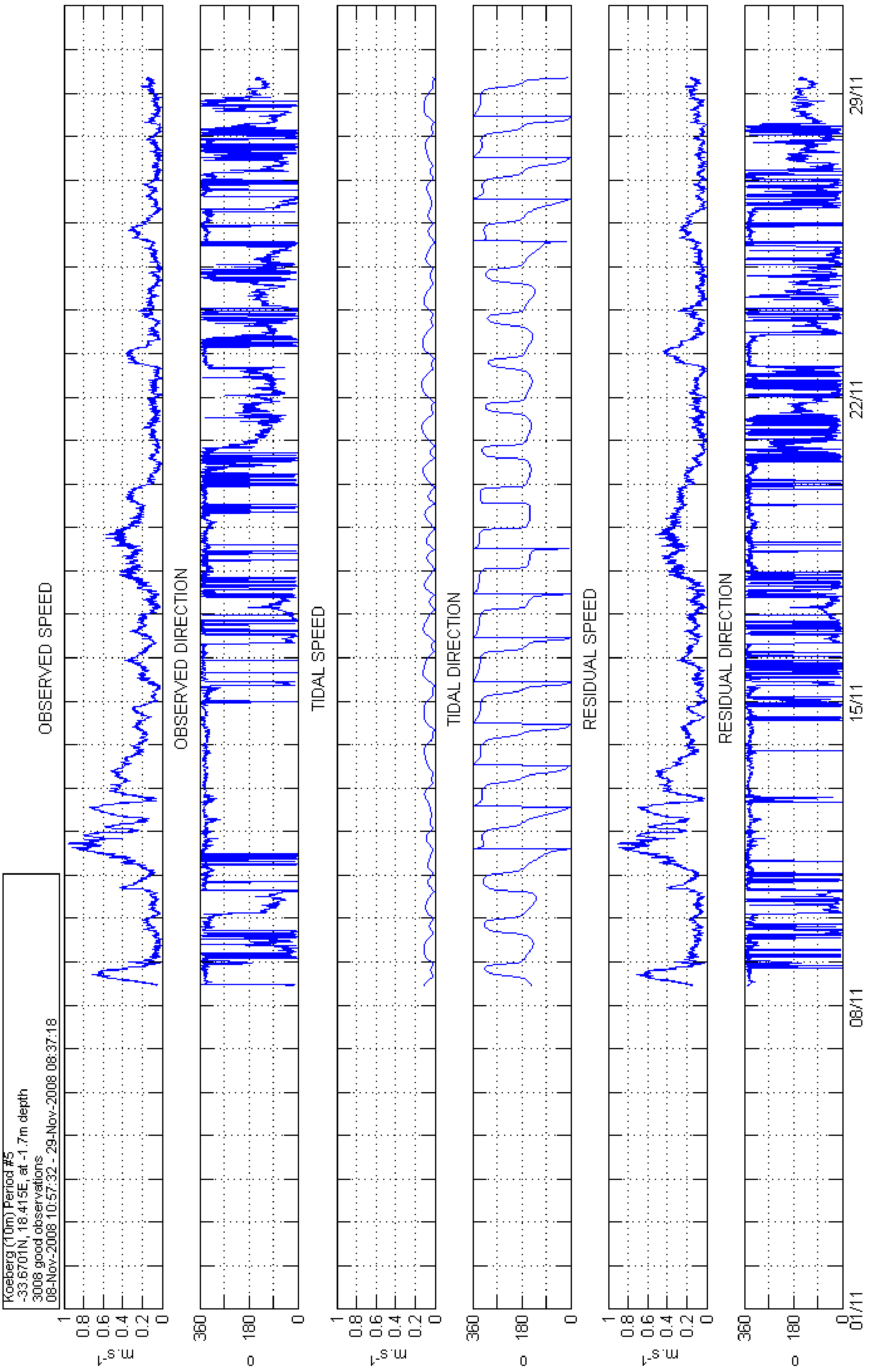


Figure 6: Time series plot of the 10m ADCP's current data at 1.7m.

5.1.1.2 Summary plot

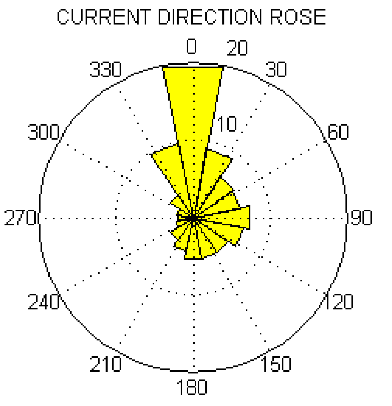
The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg (10m) Period #5
-33.6701N, 18.415E, at -8.7m depth
3010 good observations
08-Nov-2008 10:57:32 - 29-Nov-2008 08:37:18

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	6.58	6.61	6.21	6.18	7.51	6.61	5.45	5.28	5.15	4.19	3.32	2.23	1.96	2.06	2.82	3.16	75.32
0.1-0.2	5.98	2.03	0.30		0.07	0.03		0.27	0.33	0.23	0.13				0.30	2.59	12.26
0.2-0.3	3.46	0.43													0.13	2.36	6.38
0.3-0.4	1.63	0.03													0.03	0.96	2.66
0.4-0.5	1.40	0.03													0.07	0.37	1.86
0.5-0.6	0.60														0.17	0.13	0.90
0.6-0.7	0.27															0.17	0.43
0.7-0.8	0.03														0.03	0.07	0.13
0.8-0.9																0.07	0.07
0.9-1																	0.00
Σ	19.93	9.14	6.51	6.18	7.57	6.64	5.45	5.55	5.48	4.42	3.46	2.23	1.96	2.06	3.55	9.87	100.00



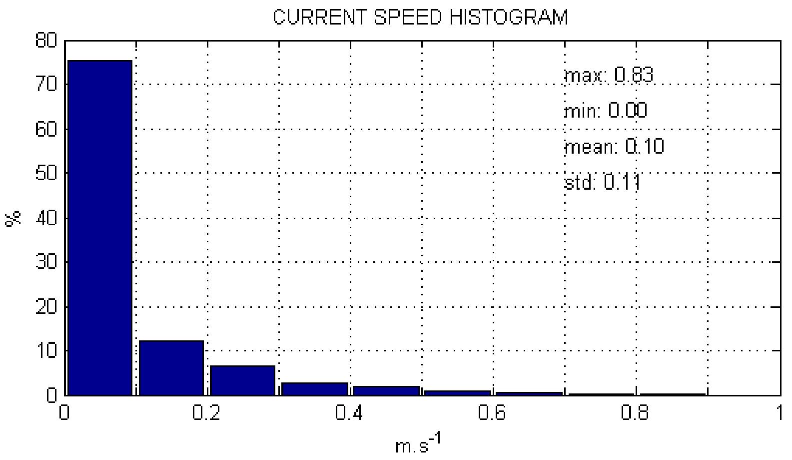
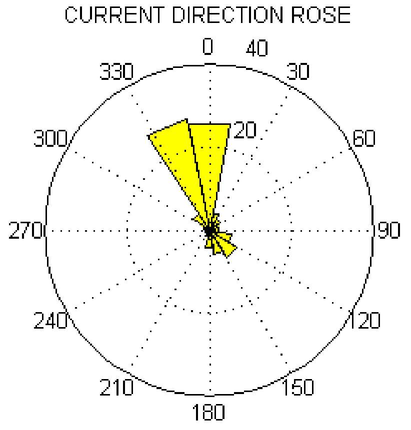


Figure 7: Summary plot of the 10m ADCP's current data at 8.7m.

Koeberg (10m) Period #5
-33.6701N, 18.415E, at -4.2m depth
3011 good observations
08-Nov-2008 10:57:32 - 29-Nov-2008 08:37:18

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	8.10	3.72	2.92	2.32	2.23	5.41	7.37	5.08	2.82	1.69	1.06	1.03	0.76	1.43	3.52	7.97	57.46
0.1-0.2	9.30	0.56	0.10			0.13	0.56	0.83	1.33	0.23	0.03			0.03	0.90	6.84	20.86
0.2-0.3	3.82	0.03													0.23	5.21	9.30
0.3-0.4	2.62													0.03		3.75	6.41
0.4-0.5	0.60														0.07	1.46	2.13
0.5-0.6	0.96														0.03	0.80	1.79
0.6-0.7	0.50														0.07	0.70	1.26
0.7-0.8	0.13														0.03	0.37	0.53
0.8-0.9	0.10															0.10	0.20
0.9-1																0.07	0.07
Σ	26.14	4.32	3.02	2.32	2.23	5.55	7.94	5.91	4.15	1.93	1.10	1.03	0.76	1.49	4.85	27.27	100.00



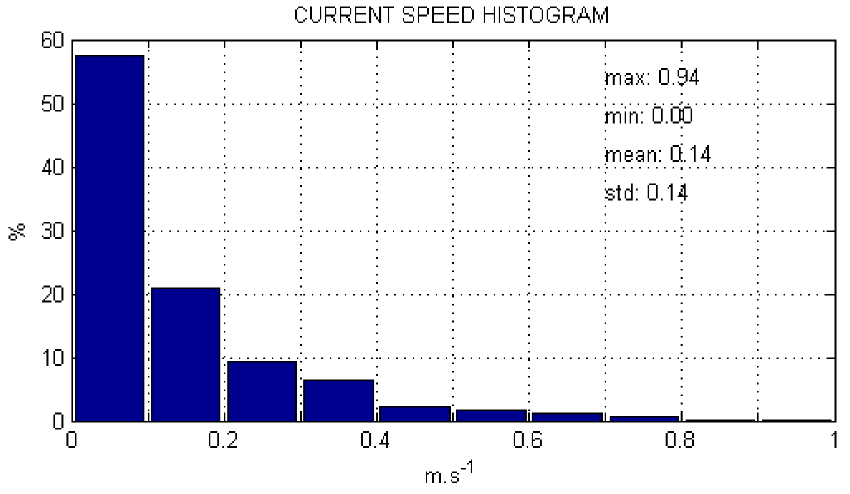


Figure 8: Summary plot of the 10m ADCP's current data at 4.2m.

Koeberg (10m) Period #5
-33.6701N, 18.415E, at -1.7m depth
3008 good observations
08-Nov-2008 10:57:32 - 29-Nov-2008 08:37:18

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	4.22	2.76	2.99	2.83	3.66	3.13	2.36	2.16	1.50	1.26	0.73	0.63	0.63	1.20	3.22	4.42	37.70
0.1-0.2	5.59	1.56	1.36	1.10	1.76	2.16	1.60	0.57	0.10	0.10	0.03		0.03	0.20	2.26	8.64	27.06
0.2-0.3	3.22	0.40				0.03			0.03		0.07			0.03	0.76	11.47	16.02
0.3-0.4	1.53								0.03	0.03				0.03	0.47	7.21	9.31
0.4-0.5	0.27														0.20	4.22	4.69
0.5-0.6	0.13														0.03	1.60	1.76
0.6-0.7	0.13														0.13	1.53	1.80
0.7-0.8	0.03														0.03	1.13	1.20
0.8-0.9	0.03															0.27	0.30
0.9-1																0.17	0.17
Σ	15.16	4.72	4.36	3.92	5.42	5.32	3.96	2.73	1.66	1.40	0.83	0.63	0.66	1.46	7.11	40.66	100.00

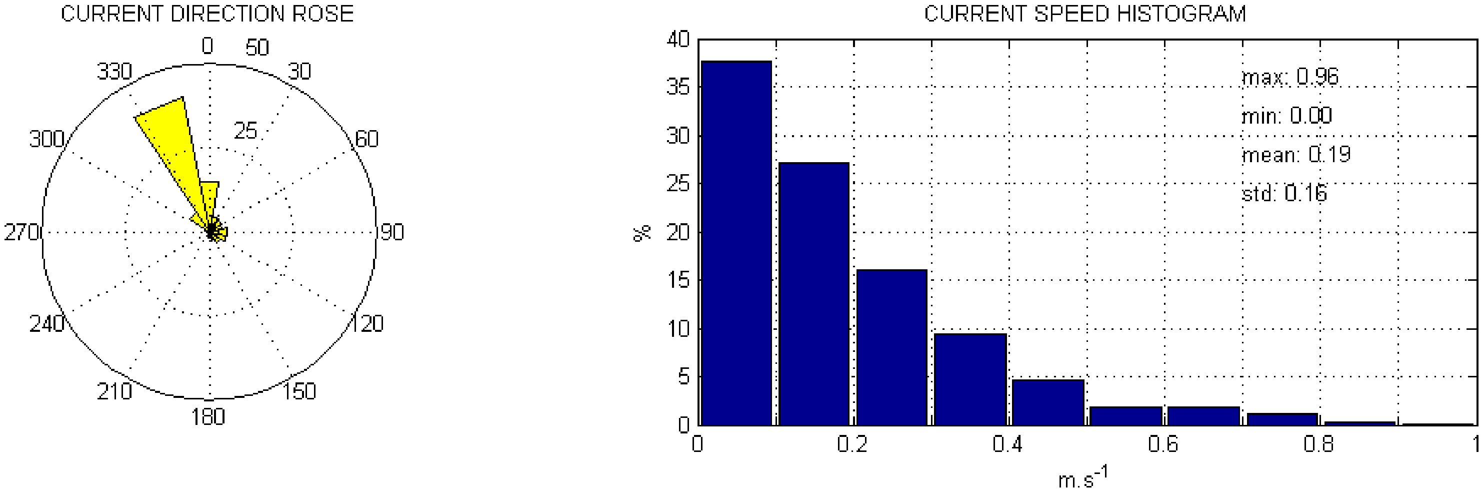


Figure 9: Summary plot of the 10m ADCP's current data at 1.7m.

5.1.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

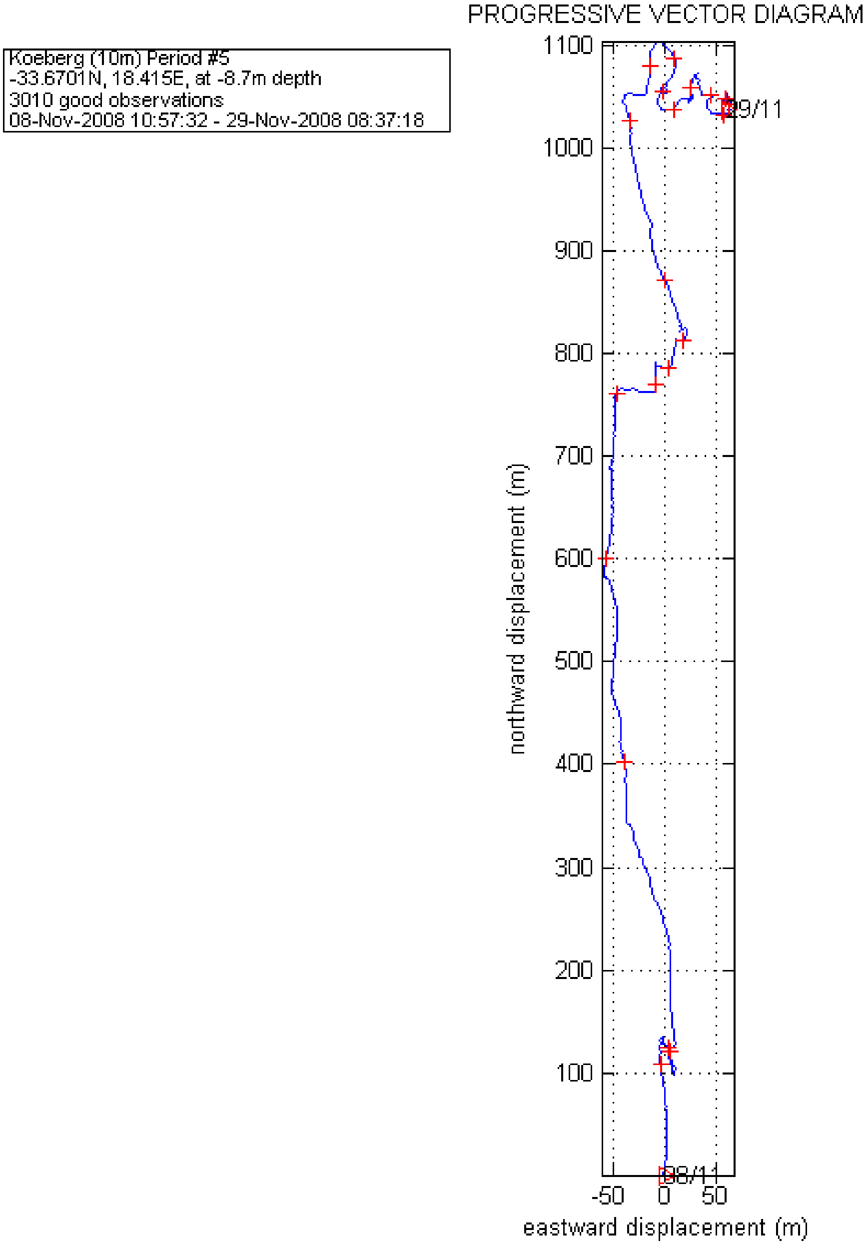


Figure 10: Progressive vector plot of current data at 8.7m.

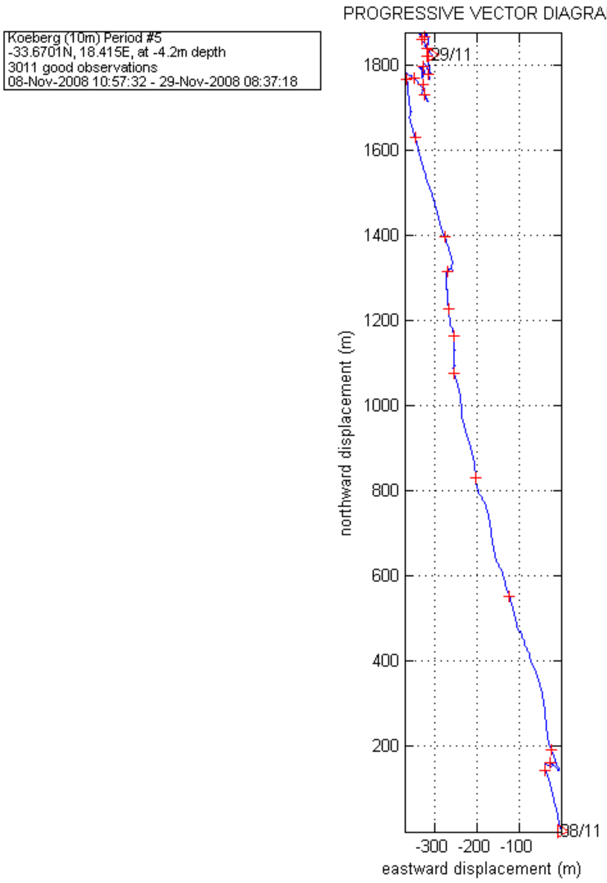


Figure 11: Progressive vector plot of current data at 4.2m.

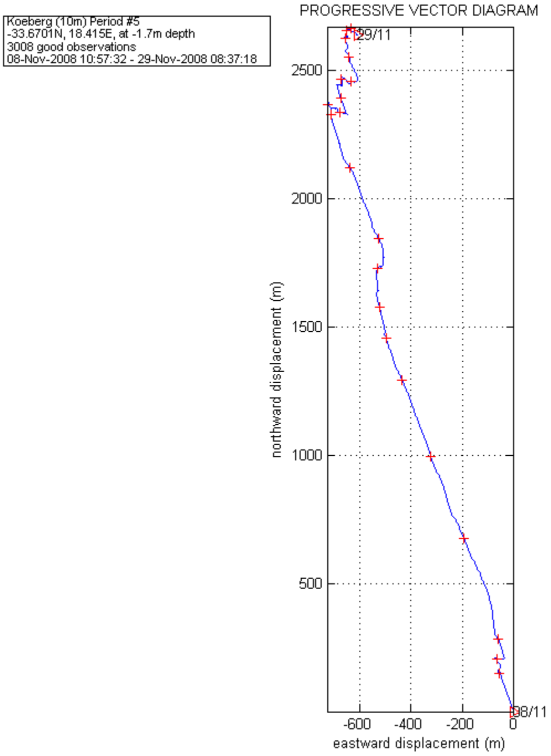


Figure 12: Progressive vector plot of current data at 1.7m.

5.1.2 Wave Data.

5.1.2.1 Hs and Tp summary plot

Figure 13 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.1.2.2 Hs and Dp summary plot

Figure 14 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.1.2.3 Tp and Dp summary plot

Figure 15 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

Koeberg (10m) Period #5
-33.6701N, 18.415E, at 10m depth
500 good observations
08-Nov-2008 11:17:00 - 29-Nov-2008 07:17:00

JOINT DISTRIBUTION OF HS AND TP

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5																0.00
0.5-0.75						1.80										1.80
0.75-1			1.60	0.80	2.40	11.40	1.80									18.00
1-1.25				0.20	3.60	16.60	6.60		0.20	1.20						28.40
1.25-1.5					2.60	7.40	7.80	0.80	0.40							19.00
1.5-1.75					0.40	2.60	7.60	0.60	0.40							11.60
1.75-2						1.20	3.60	1.40	0.80							7.00
2-2.25						1.00	1.00	0.20								2.20
2.25-2.5						0.60	2.40	1.00	0.20							4.20
2.5-2.75					0.20	0.40	1.80	0.80	0.80							4.00
2.75-3						0.40	0.80	1.20								2.40
3-3.25							0.60	0.40	0.20							1.20
3.25-3.5																0.00
3.5-3.75																0.00
3.75-4								0.20								0.20
4-4.25																0.00
4.25-4.5																0.00
4.5-4.75																0.00
4.75-5																0.00
5-5.25																0.00
5.25-5.5																0.00
Σ	0.00	0.00	1.60	1.00	9.20	43.40	34.00	6.60	3.00	1.20	0.00	0.00	0.00	0.00	0.00	100.00

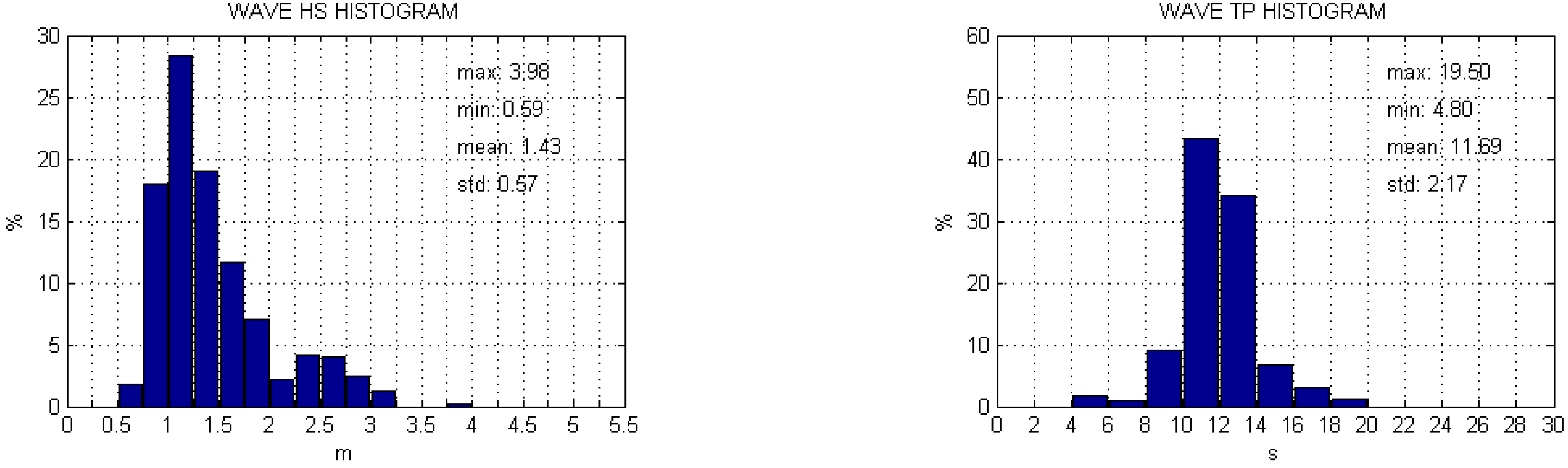


Figure 13: Summary plot of H_s and T_p.

Koeberg (10m) Period #5
-33.6701N, 18.415E, at 10m depth
500 good observations
08-Nov-2008 11:17:00 - 29-Nov-2008 07:17:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5																	0.00
0.5-0.75											1.00	0.80					1.80
0.75-1											6.40	11.20	0.20	0.20			18.00
1-1.25											7.00	21.00	0.40				28.40
1.25-1.5											2.20	16.00	0.80				19.00
1.5-1.75											0.80	10.20	0.60				11.60
1.75-2											1.00	5.80	0.20				7.00
2-2.25											0.20	2.00					2.20
2.25-2.5											0.80	3.40					4.20
2.5-2.75										0.20	2.60	1.20					4.00
2.75-3											0.60	1.80					2.40
3-3.25												1.20					1.20
3.25-3.5																	0.00
3.5-3.75																	0.00
3.75-4												0.20					0.20
4-4.25																	0.00
4.25-4.5																	0.00
4.5-4.75																	0.00
4.75-5																	0.00
5-5.25																	0.00
5.25-5.5																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	22.60	74.80	2.20	0.20	0.00	0.00	100.00

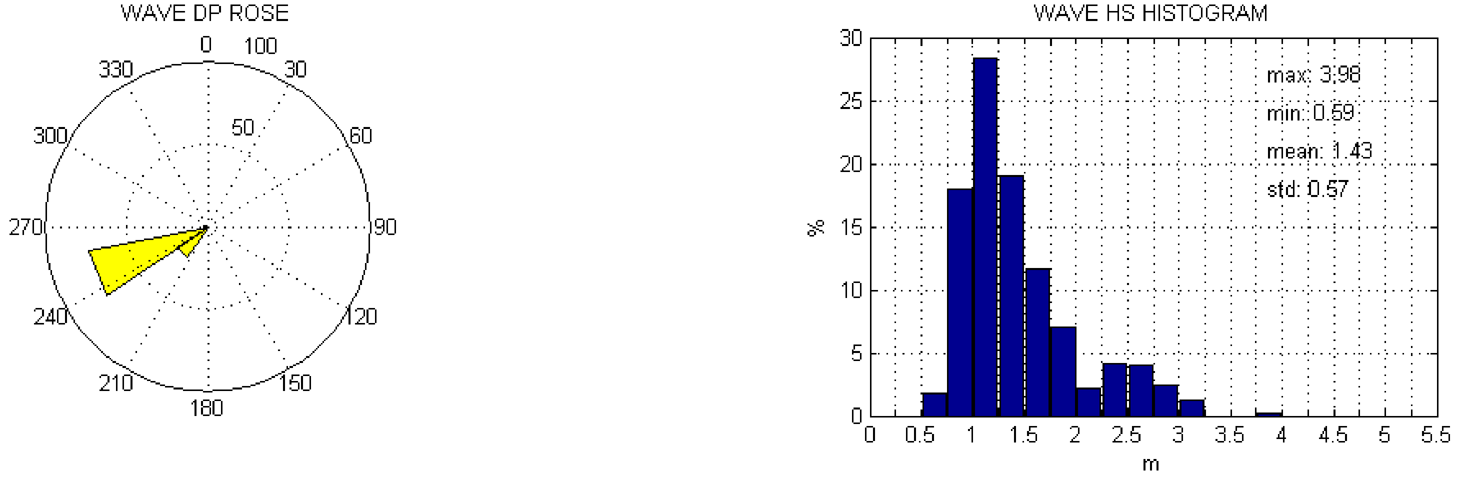


Figure 14: Summary plot of H_s and D_p.

Koeberg (10m) Period #5
-33.6701N, 18.415E, at 10m depth
500 good observations
08-Nov-2008 11:17:00 - 29-Nov-2008 07:17:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4																	0.00
4-6											1.00	0.60					1.60
6-8											0.80	0.20					1.00
8-10											3.80	4.80	0.60				9.20
10-12											10.40	32.60	0.40				43.40
12-14											5.40	27.60	0.80	0.20			34.00
14-16											1.00	5.20	0.40				6.60
16-18										0.20	0.20	2.60					3.00
18-20												1.20					1.20
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	22.60	74.80	2.20	0.20	0.00	0.00	100.00

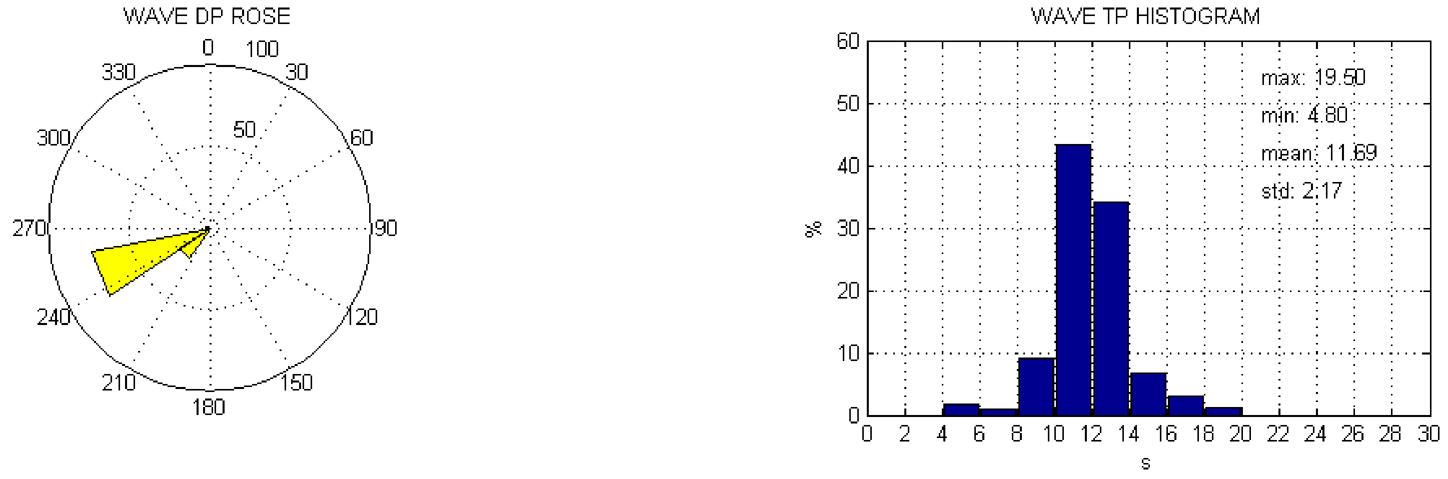


Figure 15: Summary plot of T_p and D_p.

5.1.2.4 Wave spectral plot

Figure 16 and Figure 17 display wave spectral plots for significant wave events. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

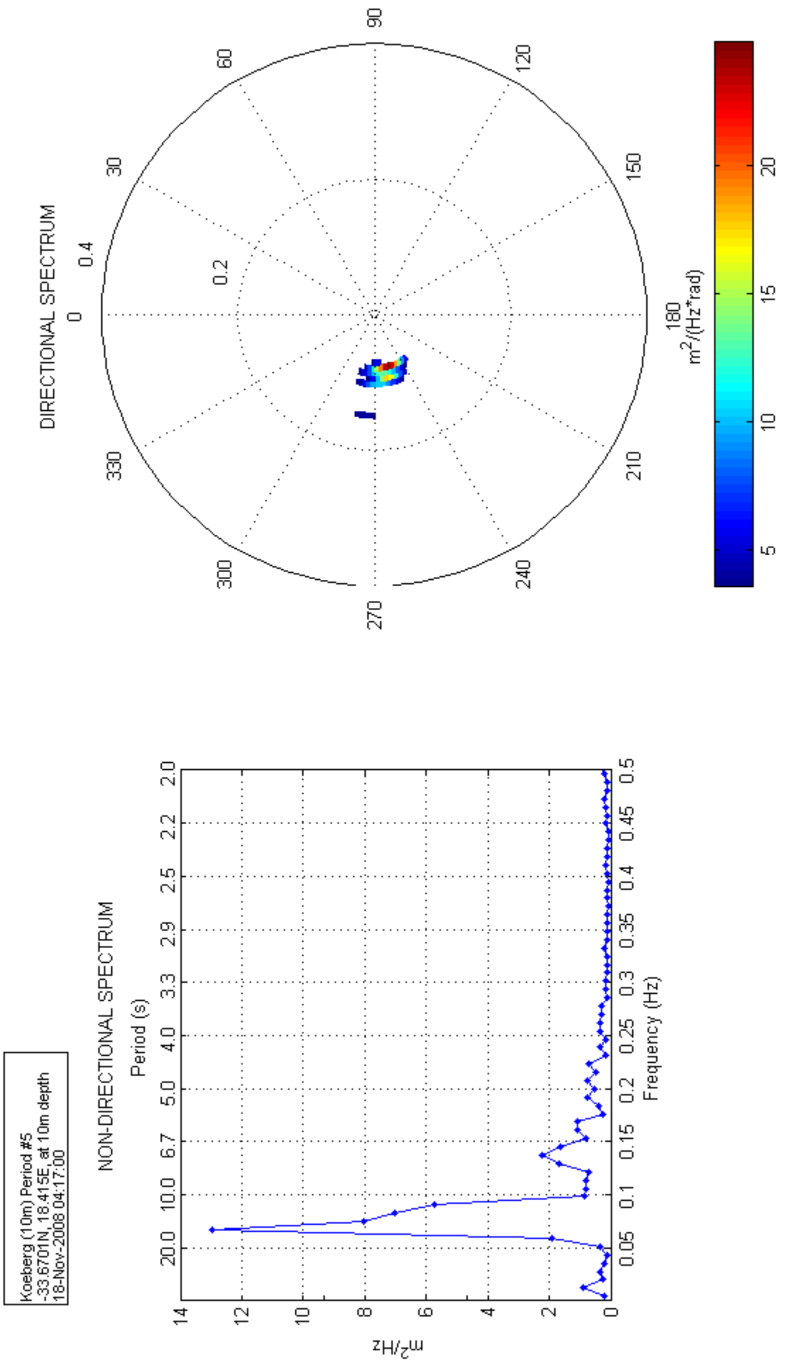


Figure 16: Wave spectra for 18th of November 2008 at 04:17:00.

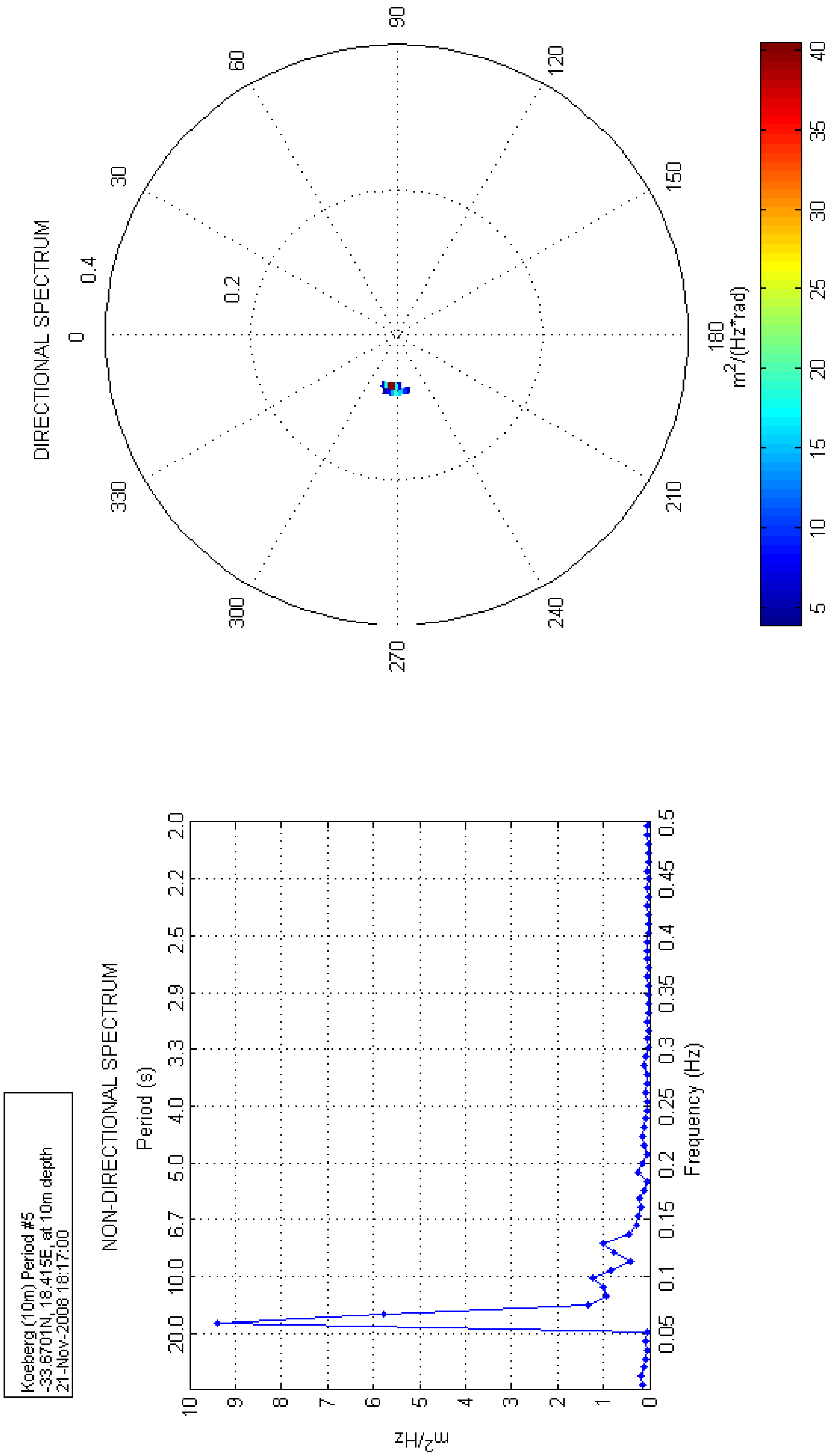


Figure 17: Wave spectra for 21st of November 2008 at 18:17:00.

5.2 30M ADCP

5.2.1 Current Data

5.2.1.1 Time series plot

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

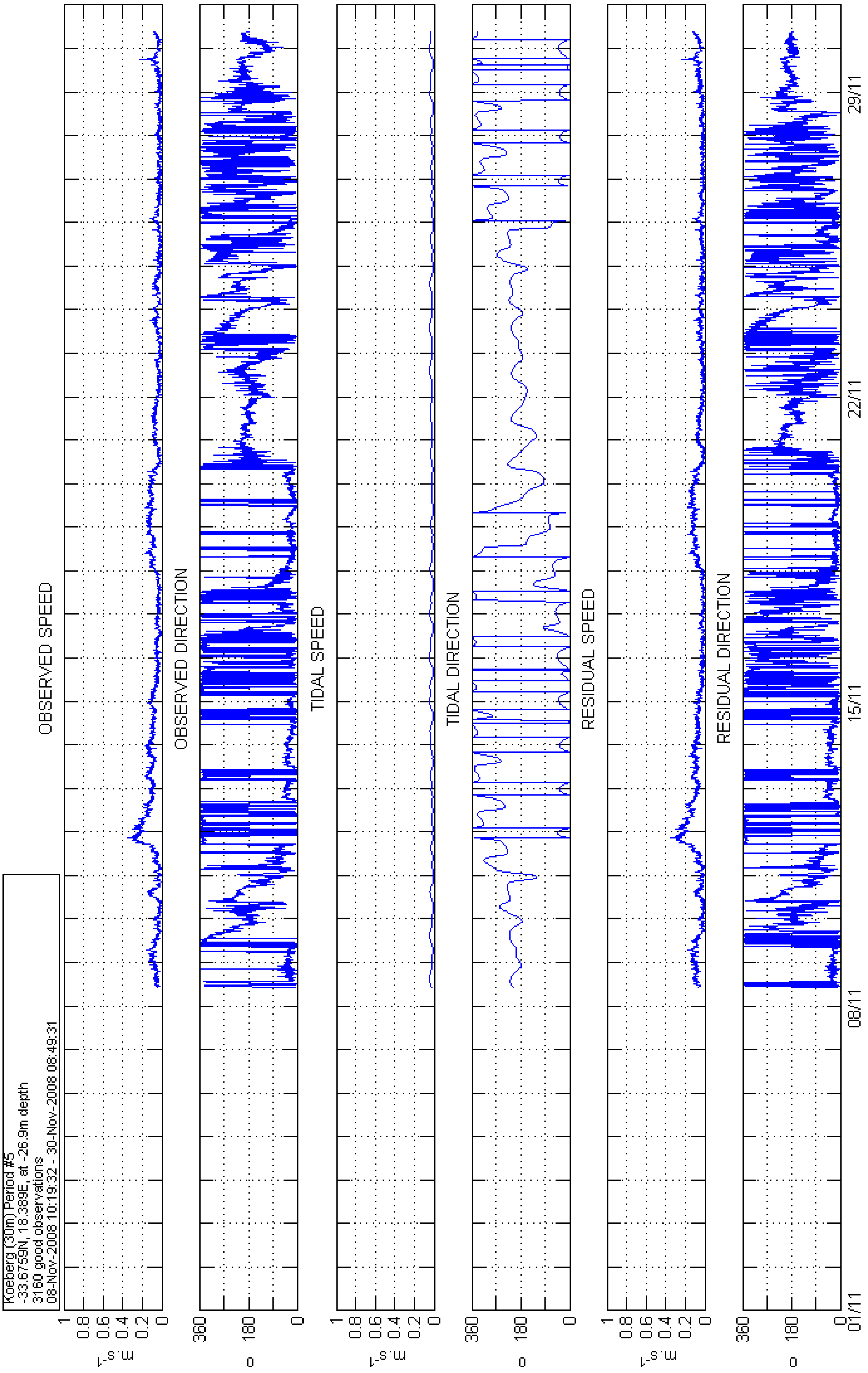


Figure 18: Time series plot of the 30m ADCP's current data at 26.9m.

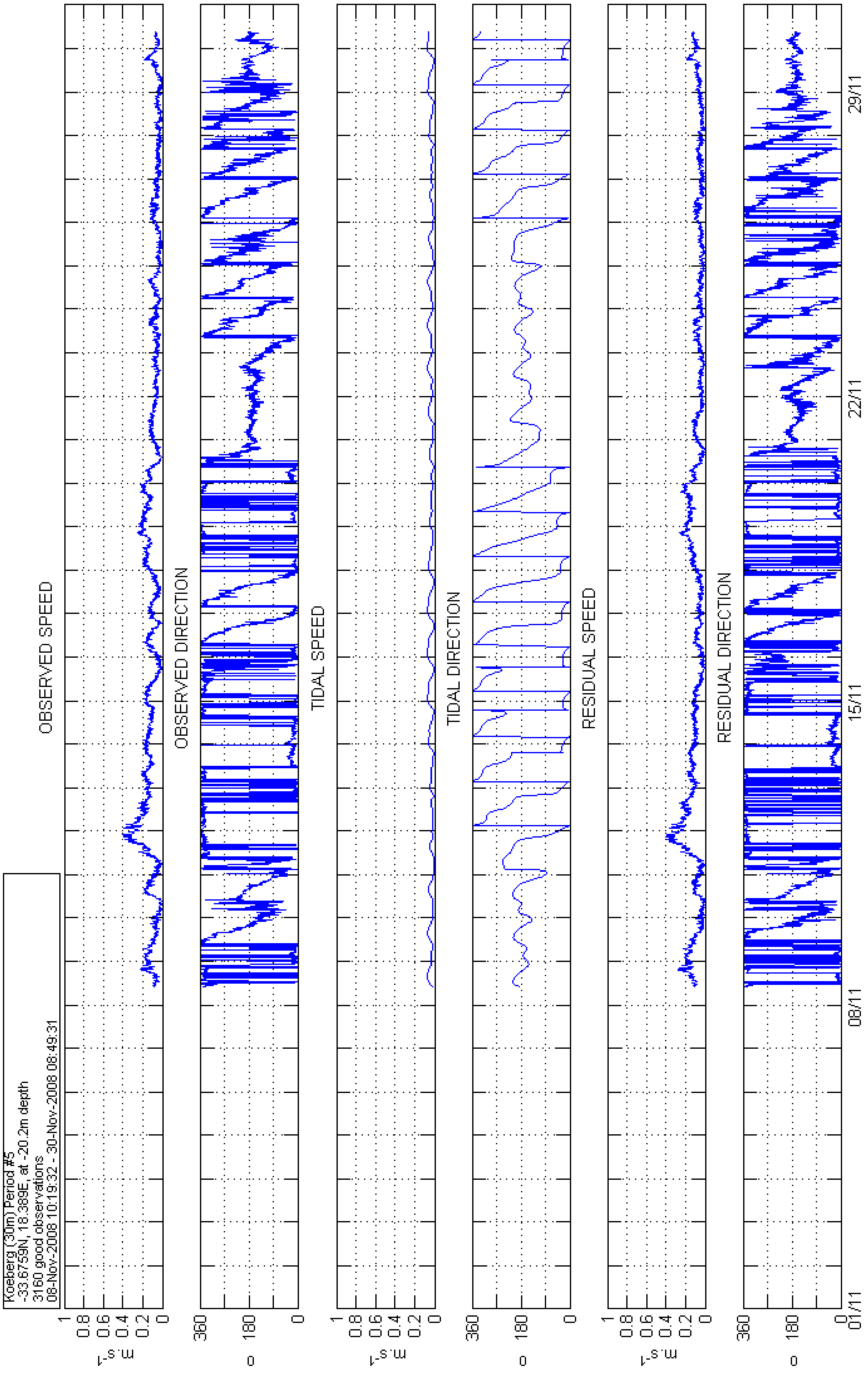


Figure 19: Time series plot of the 30m ADCP’s current data at 20.2m.

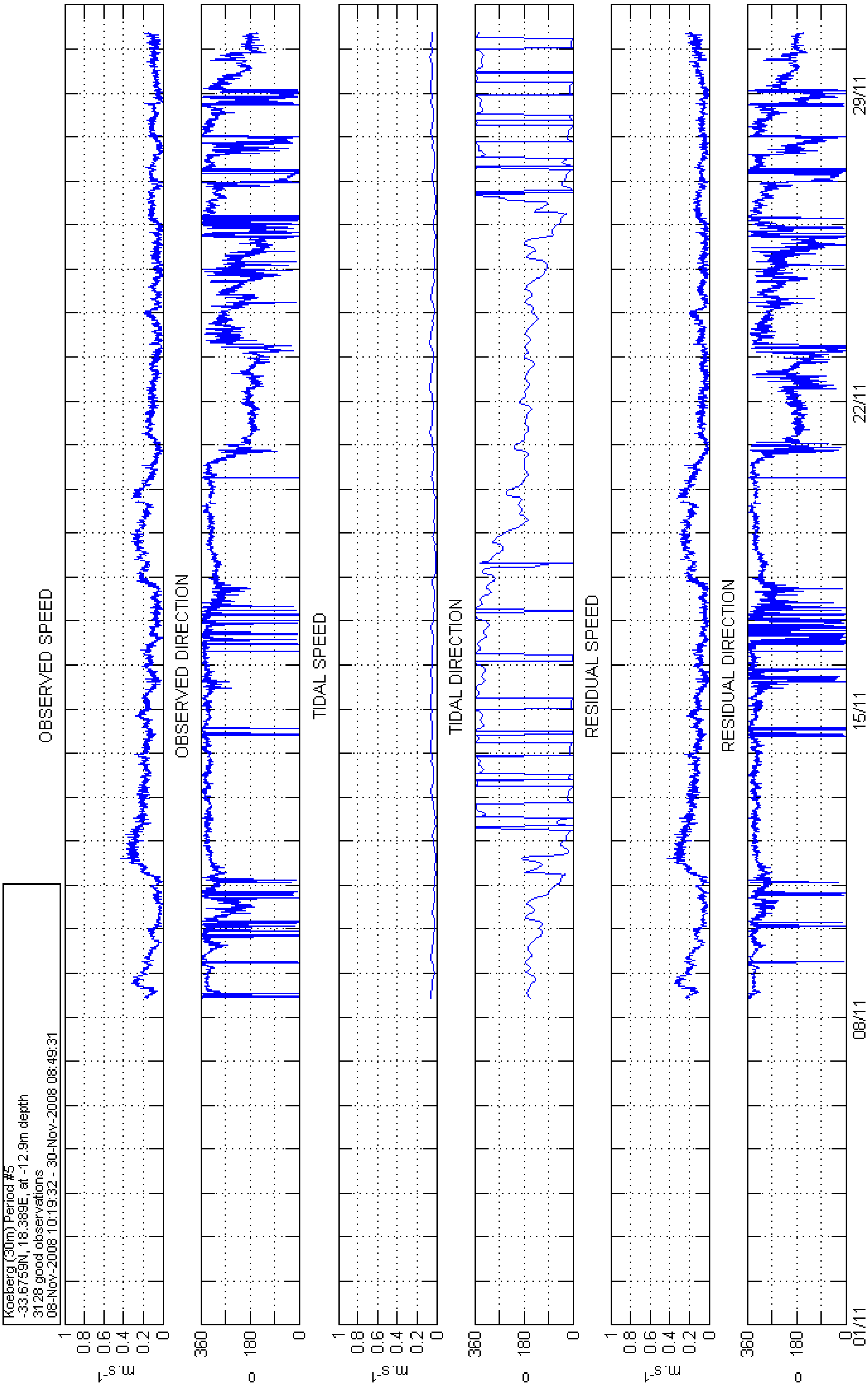
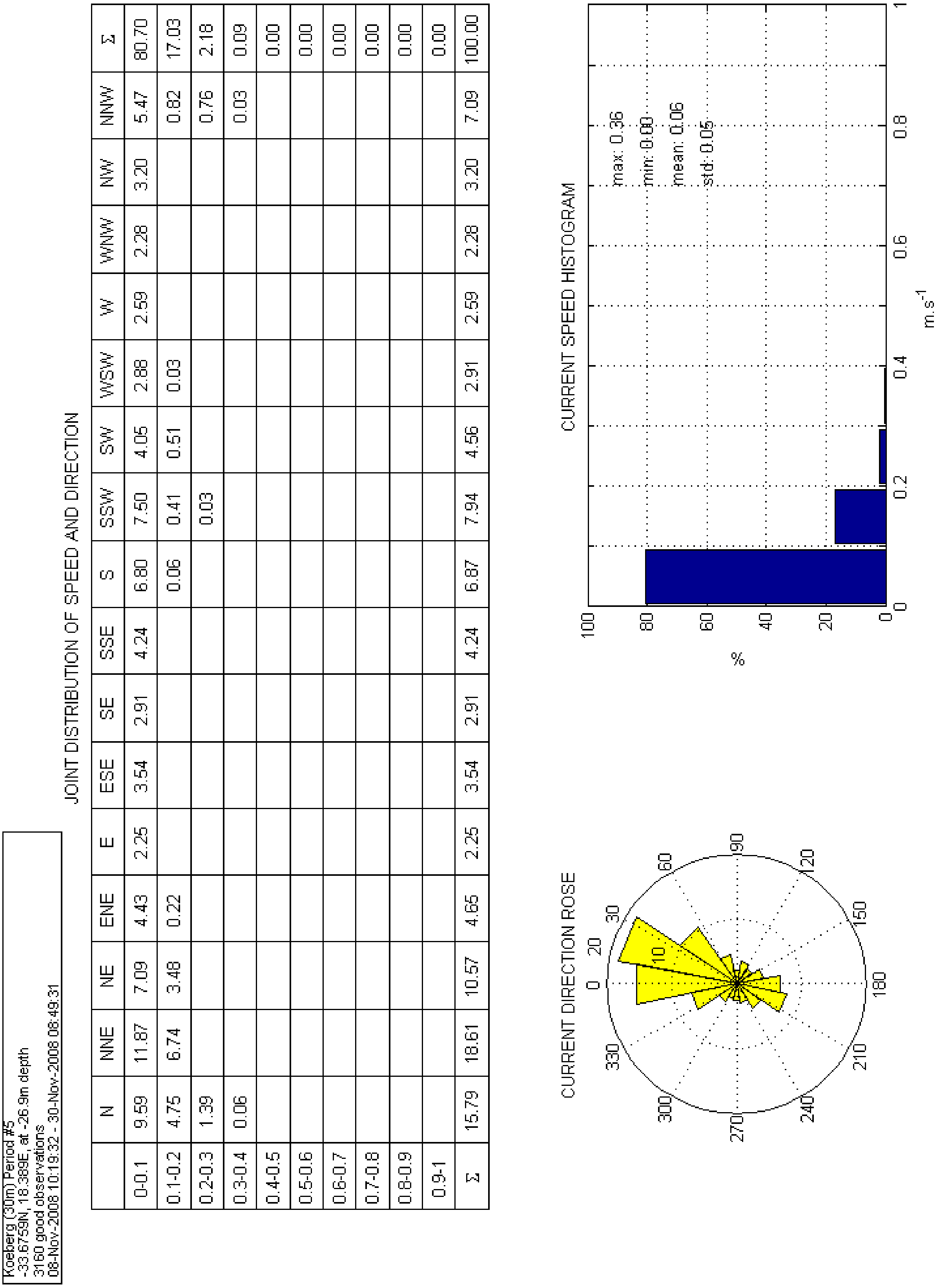


Figure 20: Time series plot of the 30m ADCP's current data at 12.9m.

5.2.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.



Koeberg (30m) Period #5
-33.6759N, 18.389E, at -26.9m depth
3160 good observations
08-Nov-2008 10:19:32 - 30-Nov-2008 08:49:31

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	9.59	11.87	7.09	4.43	2.25	3.54	2.91	4.24	6.80	7.50	4.05	2.88	2.59	2.28	3.20	5.47	80.70
0.1-0.2	4.75	6.74	3.48	0.22					0.06	0.41	0.51	0.03				0.82	17.03
0.2-0.3	1.39									0.03						0.76	2.18
0.3-0.4	0.06															0.03	0.09
0.4-0.5																	0.00
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	15.79	18.61	10.57	4.65	2.25	3.54	2.91	4.24	6.87	7.94	4.56	2.91	2.59	2.28	3.20	7.09	100.00

Figure 21: Summary plot of the 30m ADCP's current data at 26.9m.

Koeberg (30m) Period #5
-33.6759N, 18.389E, at -20.2m depth
3160 good observations
08-Nov-2008 10:19:32 - 30-Nov-2008 08:49:31

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	4.11	3.26	1.99	2.50	3.07	4.34	4.15	6.80	5.95	3.70	2.37	2.53	2.28	2.50	3.04	4.11	56.71
0.1-0.2	16.04	7.94	0.70	0.09	0.16	0.22	0.54	1.42	2.25	1.20	0.41	0.32	0.51	0.32	0.51	4.94	37.56
0.2-0.3	2.47	0.16													0.06	1.71	4.40
0.3-0.4	0.54															0.79	1.33
0.4-0.5																	0.00
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	23.16	11.36	2.69	2.59	3.23	4.56	4.68	8.23	8.20	4.91	2.78	2.85	2.78	2.82	3.61	11.55	100.00

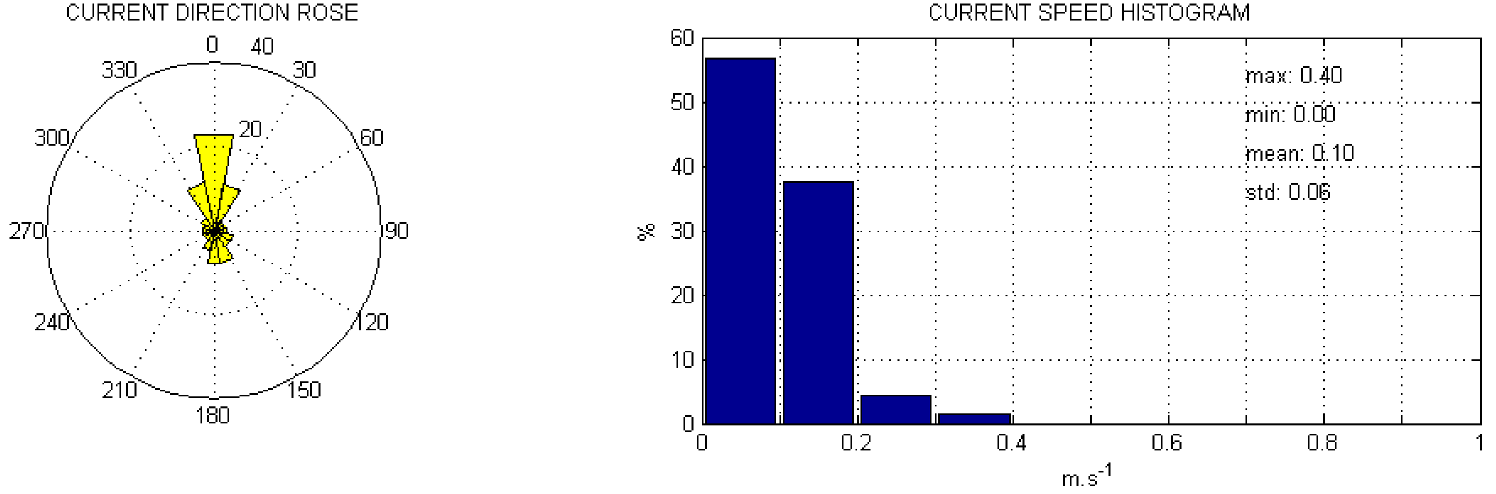
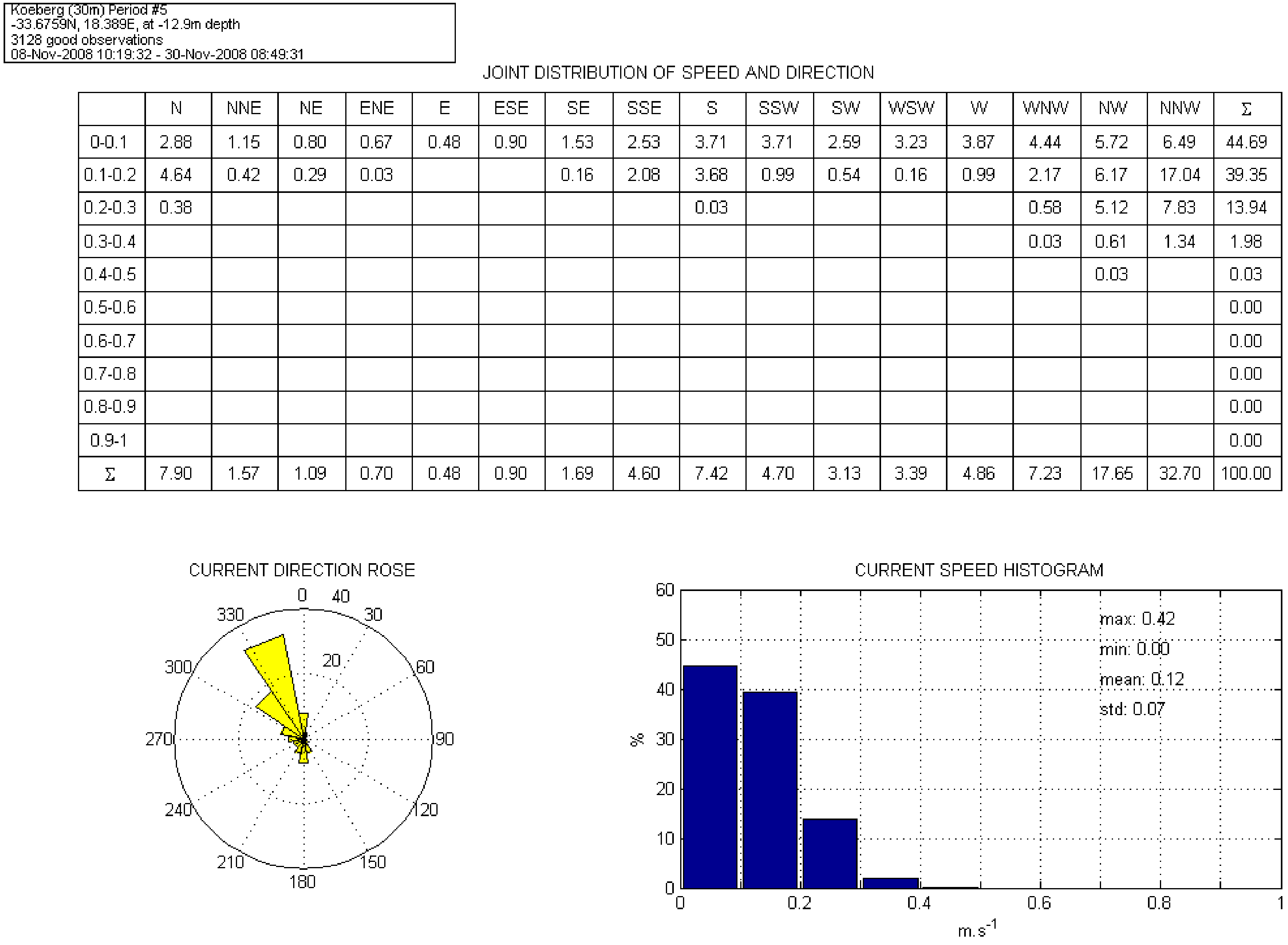


Figure 22: Summary plot of the 30m ADCP's current data at 20.2m.



Koeberg (30m) Period #5
-33.6759N, 18.389E, at -12.9m depth
3128 good observations
08-Nov-2008 10:19:32 - 30-Nov-2008 08:49:31

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	2.88	1.15	0.80	0.67	0.48	0.90	1.53	2.53	3.71	3.71	2.59	3.23	3.87	4.44	5.72	6.49	44.69
0.1-0.2	4.64	0.42	0.29	0.03			0.16	2.08	3.68	0.99	0.54	0.16	0.99	2.17	6.17	17.04	39.35
0.2-0.3	0.38								0.03					0.58	5.12	7.83	13.94
0.3-0.4														0.03	0.61	1.34	1.98
0.4-0.5															0.03		0.03
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	7.90	1.57	1.09	0.70	0.48	0.90	1.69	4.60	7.42	4.70	3.13	3.39	4.86	7.23	17.65	32.70	100.00

Figure 23: Summary plot of the 30m ADCP's current data at 12.9m.

5.2.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

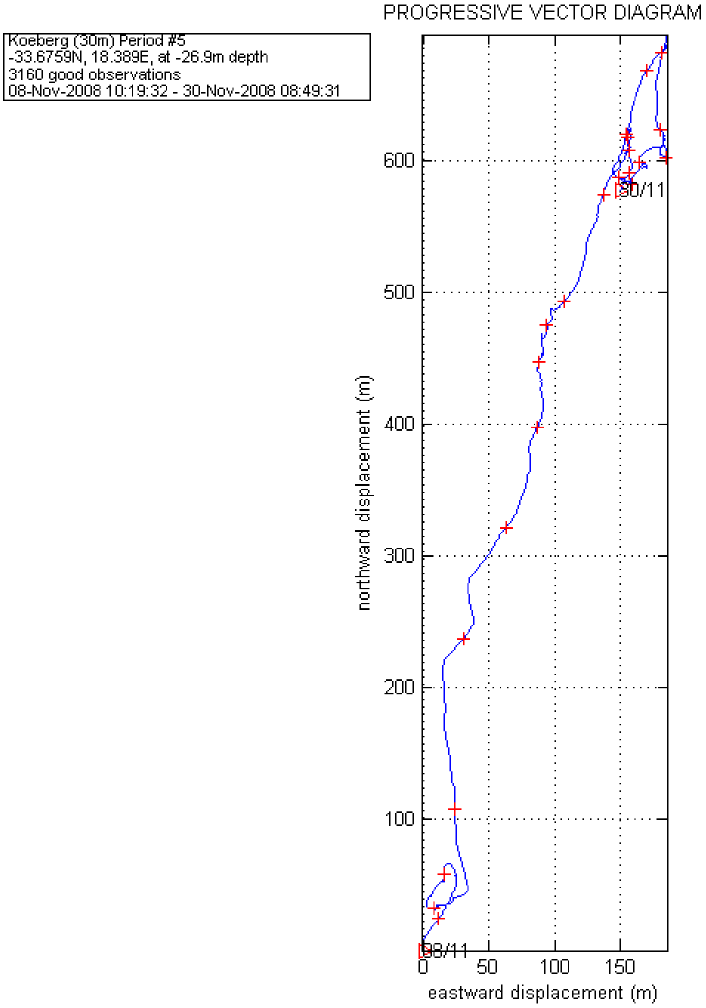


Figure 24: Progressive vector plot of current data at 26.9m.

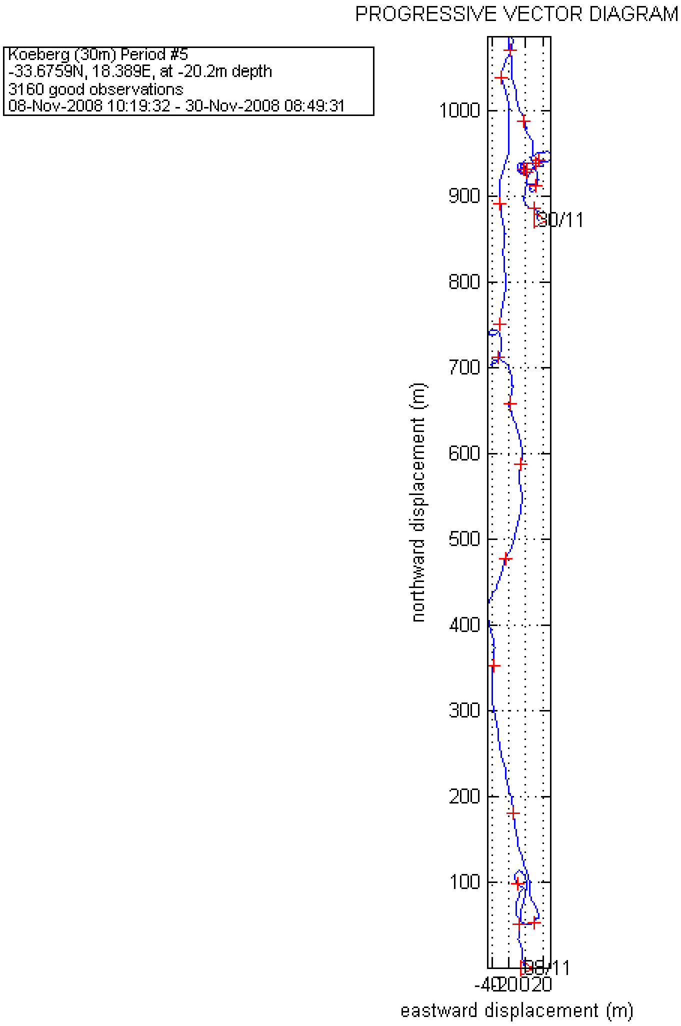


Figure 25: Progressive vector plot of current data at 20.2m.

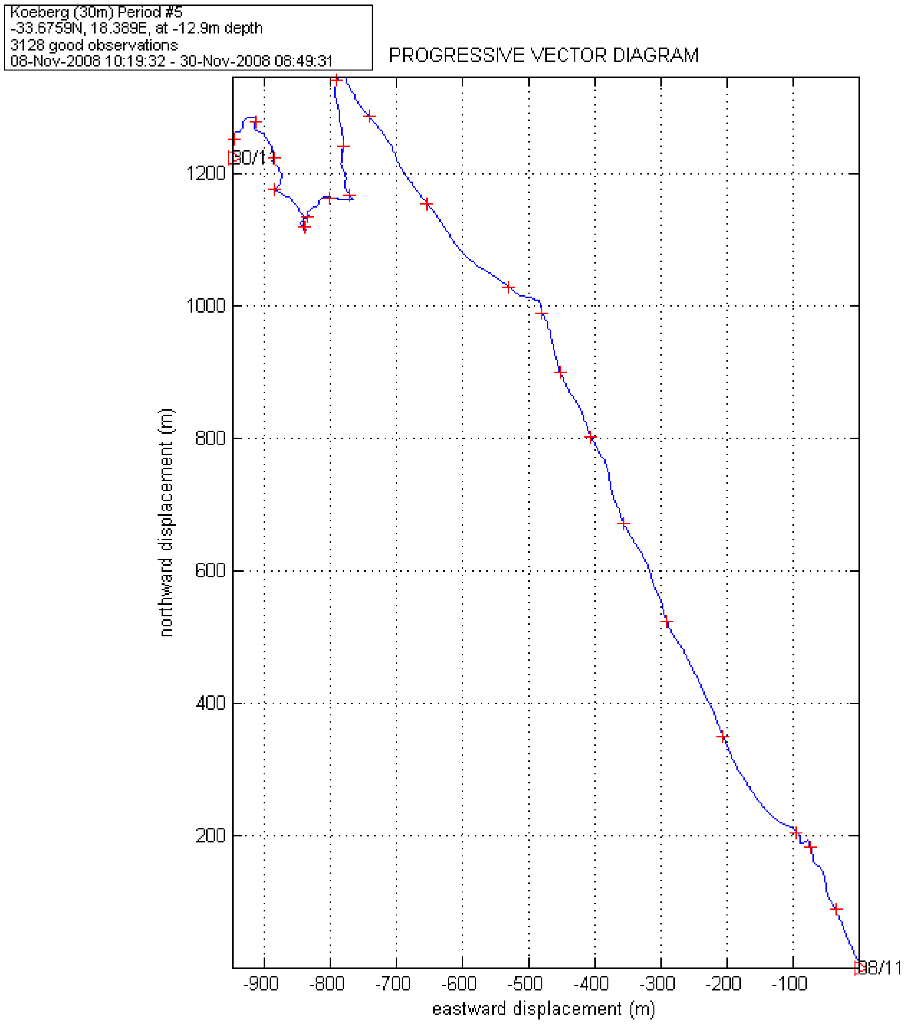


Figure 26: Progressive vector plot of current data at 12.9m.

5.2.2 Wave Data.

5.2.2.1 Hs and Tp summary plot

Figure 27 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.2.2.2 Hs and Dp summary plot

Figure 28 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.2.2.3 Tp and Dp summary plot

Figure 29 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

Koeberg (30m) Period #5
-33.6759N, 18.389E, at 30m depth
526 good observations
08-Nov-2008 10:29:00 - 30-Nov-2008 07:29:00

JOINT DISTRIBUTION OF HS AND TP

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5																0.00
0.5-0.75			0.38	0.19	0.76	3.04	0.19									4.56
0.75-1			1.33	0.38	4.18	12.93	3.04			0.19						22.05
1-1.25			0.57		4.56	12.17	7.98		0.19	0.57						26.05
1.25-1.5			0.19		2.47	7.03	5.51	0.76	0.38	0.19						16.54
1.5-1.75						2.47	6.65	0.76	0.57							10.46
1.75-2					0.76	1.14	2.85	1.33	0.76							6.84
2-2.25			0.38		0.95	1.33	1.90	0.76	0.57							5.89
2.25-2.5					0.19	0.95	1.90	0.57								3.61
2.5-2.75						0.38	2.28	0.76								3.42
2.75-3							0.38	0.19								0.57
3-3.25																0.00
3.25-3.5																0.00
3.5-3.75																0.00
3.75-4																0.00
4-4.25																0.00
4.25-4.5																0.00
4.5-4.75																0.00
4.75-5																0.00
5-5.25																0.00
5.25-5.5																0.00
Σ	0.00	0.00	2.85	0.57	13.88	41.44	32.70	5.13	2.47	0.95	0.00	0.00	0.00	0.00	0.00	100.00

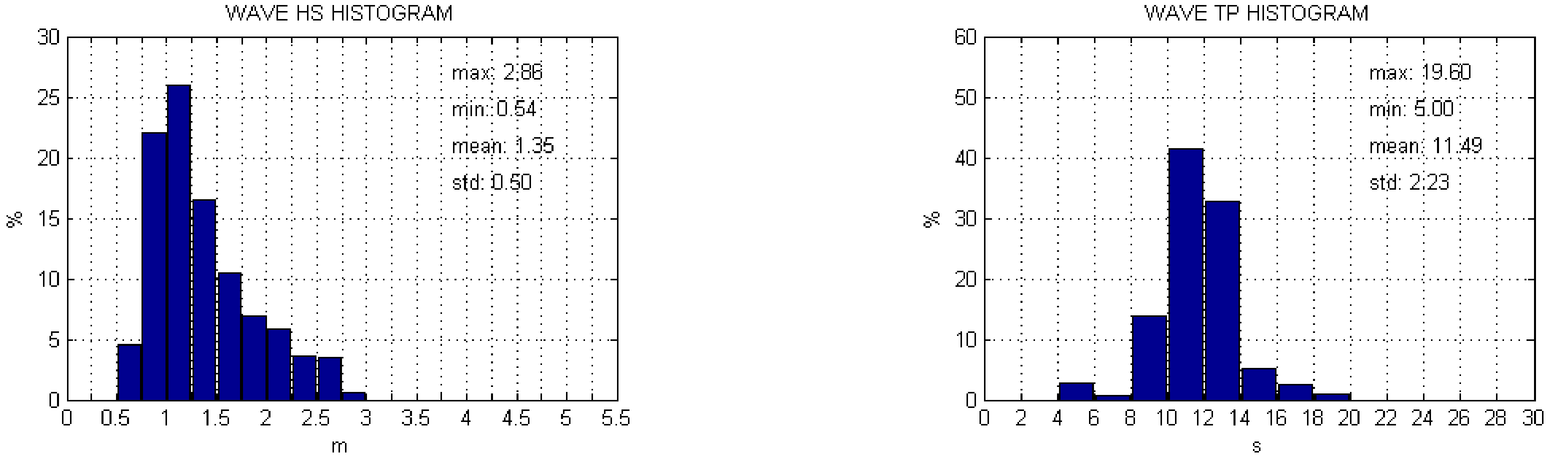


Figure 27: Summary plot of H_s and T_p.

Koeberg (30m) Period #5
-33.6759N, 18.389E, at 30m depth
526 good observations
08-Nov-2008 10:29:00 - 30-Nov-2008 07:29:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5																	0.00
0.5-0.75										0.19	2.66	1.71					4.56
0.75-1										0.57	13.12	7.79	0.38	0.19			22.05
1-1.25									0.38	0.38	9.51	13.88	1.90				26.05
1.25-1.5									0.19		4.75	11.41	0.19				16.54
1.5-1.75										0.19	2.28	7.98					10.46
1.75-2											1.90	4.56	0.38				6.84
2-2.25								0.38			3.04	2.28	0.19				5.89
2.25-2.5											0.95	2.66					3.61
2.5-2.75											2.28	0.95	0.19				3.42
2.75-3												0.57					0.57
3-3.25																	0.00
3.25-3.5																	0.00
3.5-3.75																	0.00
3.75-4																	0.00
4-4.25																	0.00
4.25-4.5																	0.00
4.5-4.75																	0.00
4.75-5																	0.00
5-5.25																	0.00
5.25-5.5																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.57	1.33	40.49	53.80	3.23	0.19	0.00	0.00	100.00

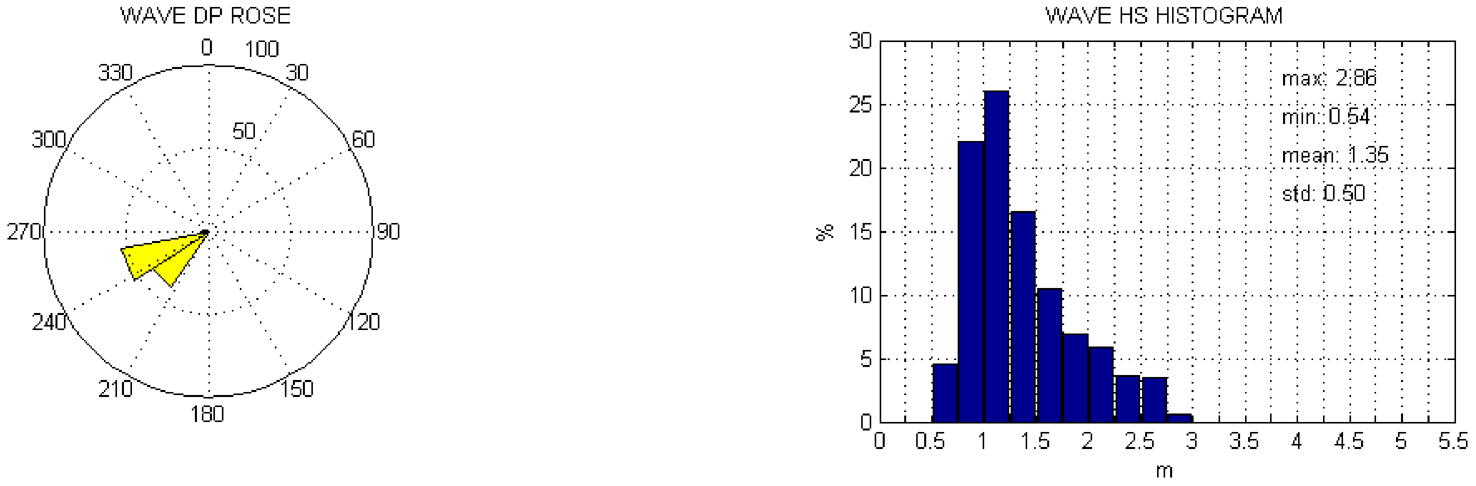
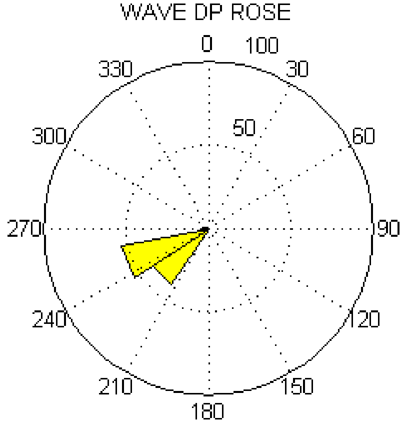


Figure 28: Summary plot of H_s and D_p.

Koeberg (30m) Period #5
-33.6759N, 18.389E, at 30m depth
526 good observations
08-Nov-2008 10:29:00 - 30-Nov-2008 07:29:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4																	0.00
4-6								0.38	0.57		1.33	0.57					2.85
6-8										0.38	0.19						0.57
8-10										0.19	7.22	6.08	0.38				13.88
10-12										0.57	20.34	19.39	0.95	0.19			41.44
12-14										0.19	9.89	21.29	1.33				32.70
14-16											1.52	3.42	0.19				5.13
16-18												2.28	0.19				2.47
18-20												0.76	0.19				0.95
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.57	1.33	40.49	53.80	3.23	0.19	0.00	0.00	100.00



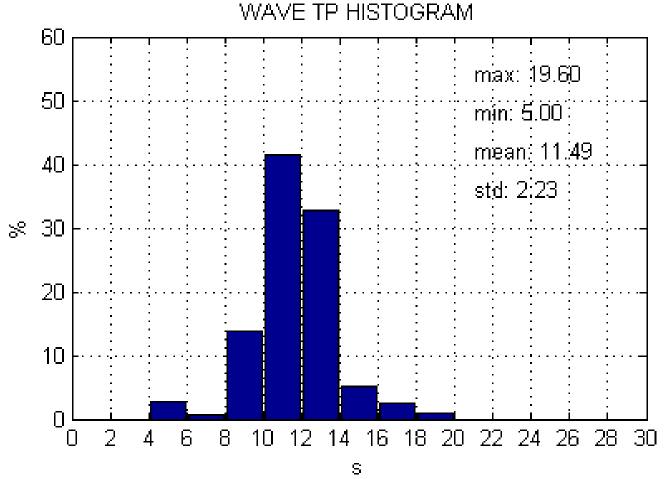


Figure 29: Summary plot of T_p and D_p.

5.2.2.4 Wave spectral plot

Figure 30 displays wave spectral plots for a significant wave event. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

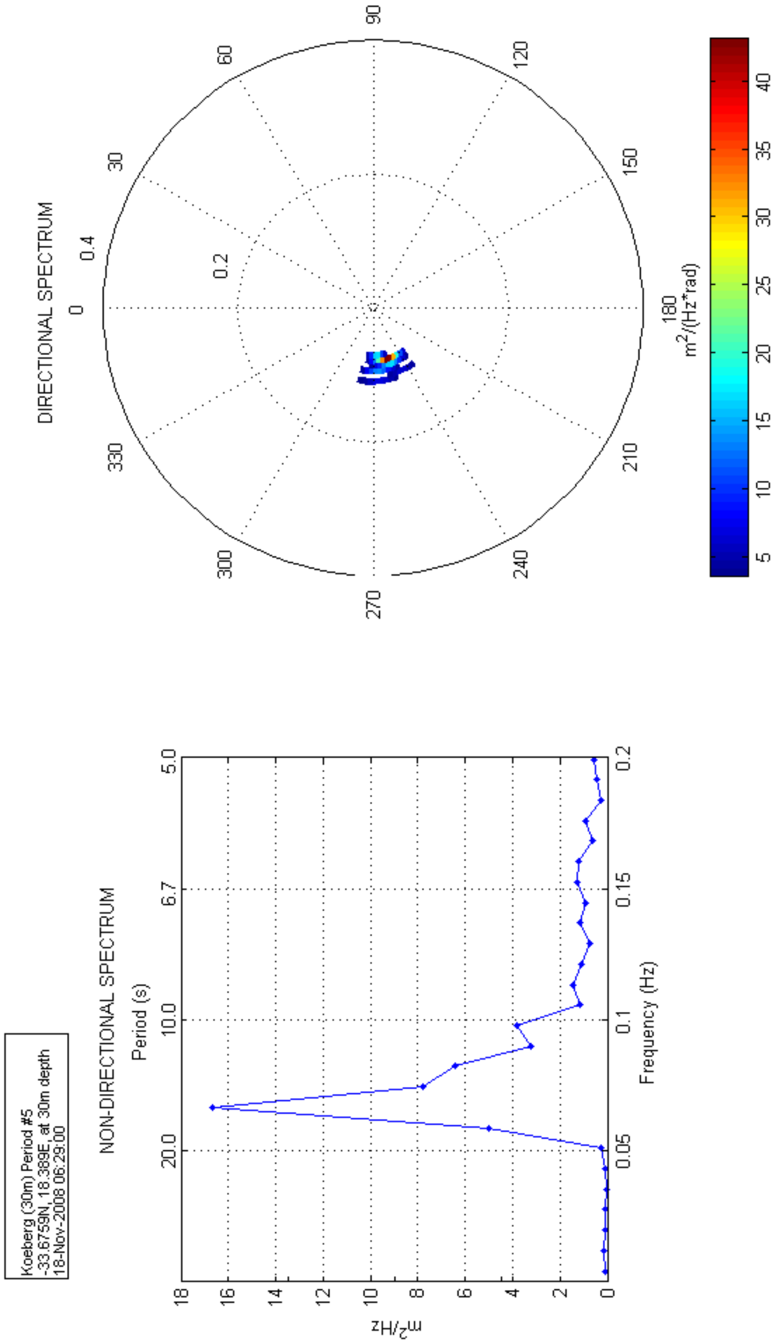


Figure 30: Wave spectra for 18th of November 2008 at 06:29:00.

5.3 COMPARISON PLOTS

5.3.1 Hs, Tp and Dp time series plots for 10m and 30m ADCPs.

Figure 31 displays a time series plot of the main wave parameters:

- The first (upper) panel is of the significant wave height (Hs).
- The second panel is of the peak period (Tp).
- The third panel is of the peak wave direction (Dp).

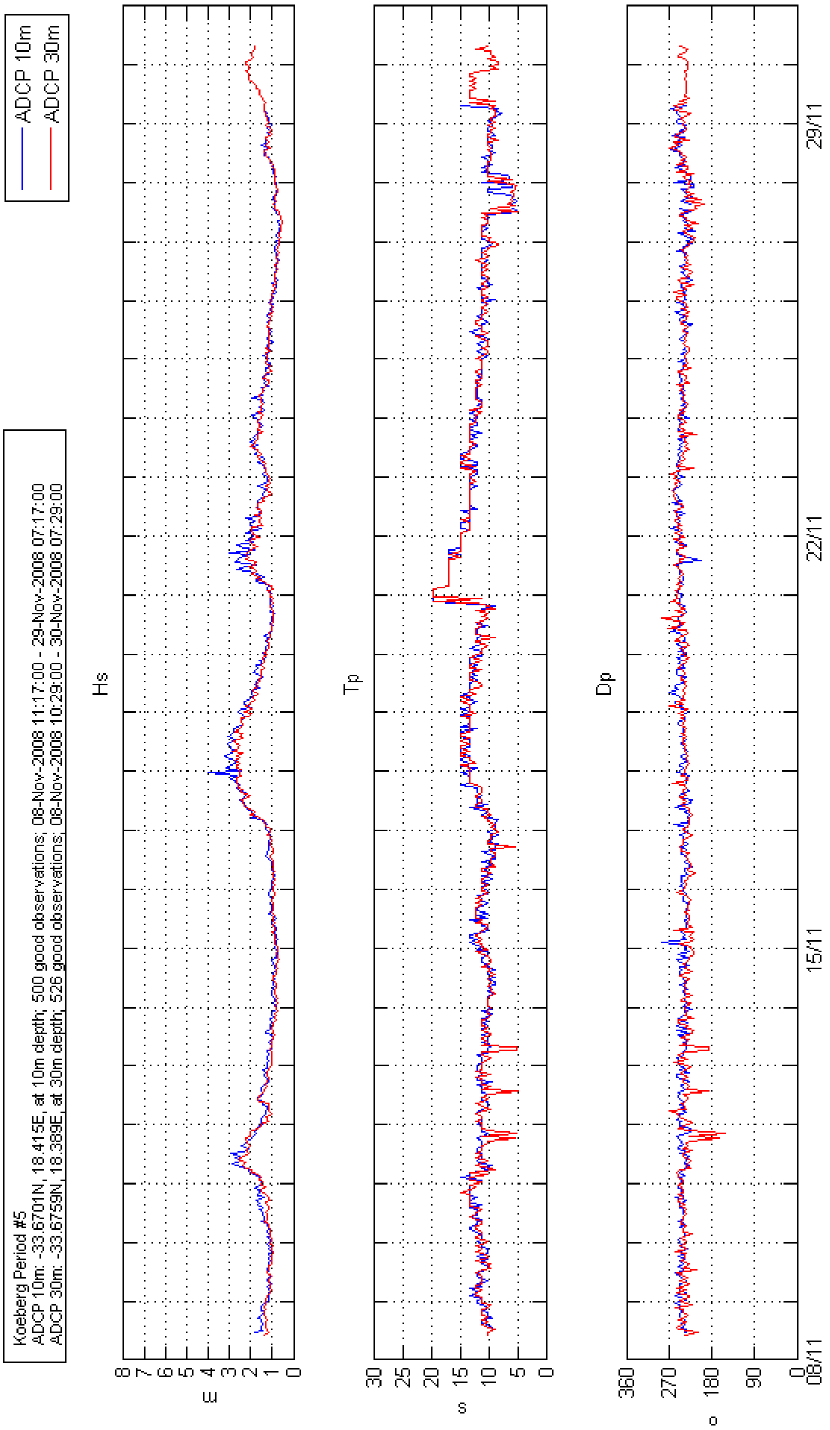


Figure 31: Wave Hs, Tp, and Dp for 10m and 30m ADCP.

5.3.2 Water properties: RBR-CT loggers, Thermister String and ADCPs temperature sensors.

Figure 32 displays a time series plot, which consists of:

- The first panel is of the observed water temperature from surface and bottom RBR loggers, as well as ADCP temperature sensor against time.
- The second panel is of the derived salinity from the two RBR loggers against time.

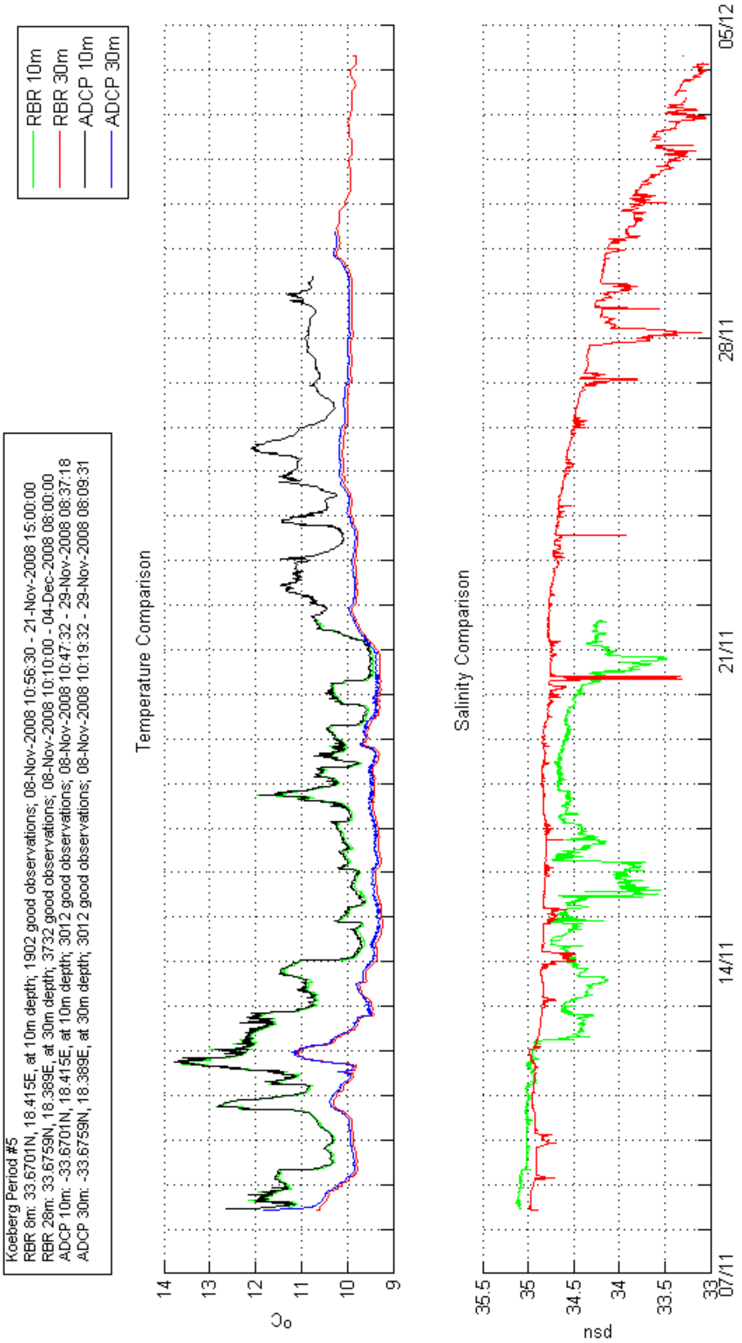


Figure 32: Time series of temperature and salinity from the RBR logger and ADCPs.

6. DISCUSSION

The fifth set of oceanographic data collected at Koeberg for the period between November 8th and December 4st 2008 has been presented in this report. The measurements taken fall within a larger dataset being compiled to assist a preliminary safety survey of multiple sites around the South African coast reports for Eskom.

At the Koeberg site, 2 600 kHz ADCPs and 2 RBR-CT loggers have been deployed to measure currents, waves and water temperature and salinity. The ADCPs are fixed on a frame at ~10m and ~30m. The RBR loggers are attached to the frame.

An unfortunate mix-up occurred in the field during the redeployment of the ADCPs on November 8th 2008 (SV4). The unit configured for the 10m site was deployed at 30m and the one configured for the 30m site was deployed at 10m. Consequently at the 30m site, current data is only available for bins between ~10m and ~25m depth. This had no impact on data return for the 10m site.

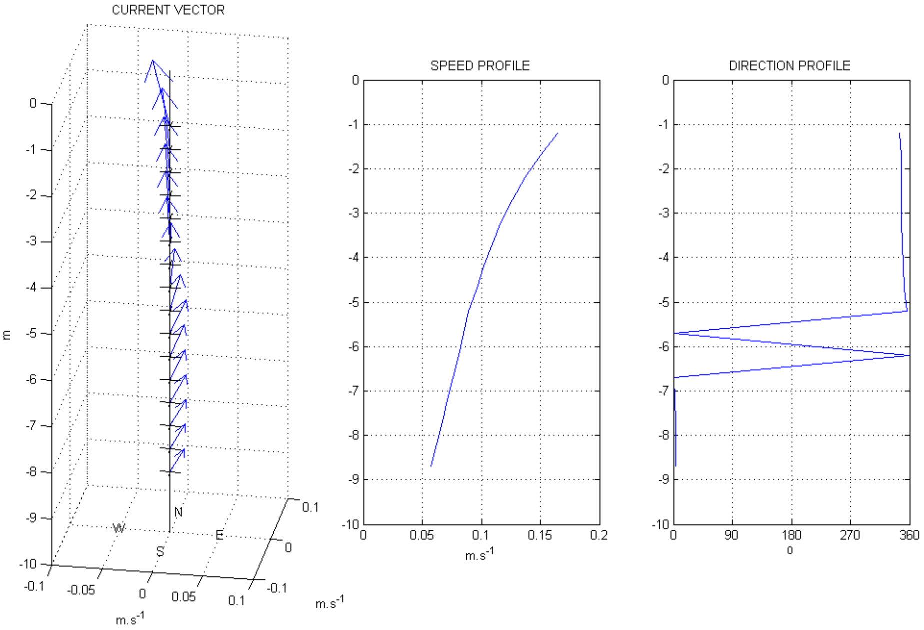


Figure 33: Mean profile plot for 10m ADCP.

The average surface current speed at the 10m site was ~0.19ms^{-1}, decreasing to ~0.1ms^{-1} at ~9m depth. The flow throughout the water column was predominantly towards the North. The mean current profile plot, presented in Figure 33, shows the gradual decrease in the vector mean speed.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.43m, with a wave period of 11.69s and mean direction to W/WSW.

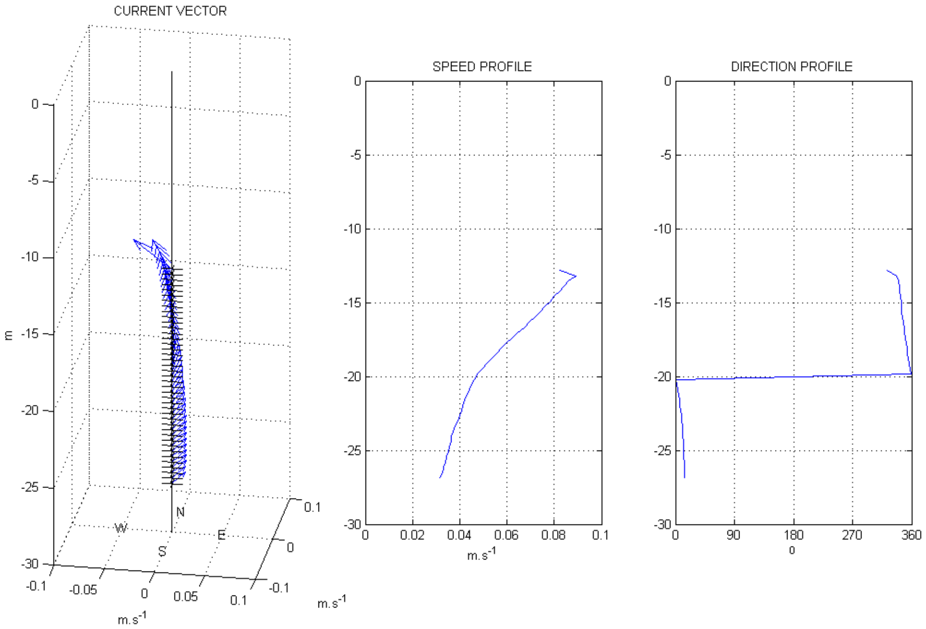


Figure 34: Mean profile plot for 30m ADCP.

The average current speed at the 30m site was ~0.12ms^{-1} at ~13m depth, decreasing to ~0.06ms^{-1} at ~27m depth. The flow throughout the water column was predominantly towards the North.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.35m, with a wave period of 11.49s and mean direction to WSW/SW.

The temperature values recorded from the various independent instruments are in agreement with each other.

7. INSTRUCTION PARTICULARS FOR SERVICE VISIT FIVE

7.1 ADCP RECOVERY AND RE-DEPLOYMENT SHEETS

10m ADCP.

1. RECOVERY Site Name: Koeberg 10m Date: 4 Dec 2008.

Instrument type and serial number			RDI	11424
Recovery date and time	LTx	GMT	08h30 4 Dec 2008	
Latitude **(do not ignore – if same, please indicate)**			33 40.206	
Longitude **(do not ignore – if same, please indicate)**			18 24.897	
Switch off date and time	LTx	GMT	14h00 4 Dec 2008	
File size			207MB	
Was the data copied to memory card?			Y x	N

2. RE-DEPLOYMENT Site Name: Koeberg 10m Date 6 Dec 2008 .

Instrument type and serial number (do not ignore – if same, please indicate)	RDI	10841
Install a new battery and/or check the voltage		1*44.9V
Frequency of unit being used	600KHz	
Depth range	10m	
Number of bins (calculated automatically)	42	
Bin Size (calculated automatically)	0.35	
Wave burst duration	41min	
Time between wave bursts	60min	
Pings per ensemble	500	
Ensemble interval	10min	
Deployment duration	15 days	
Transducer depth	10m	
Any other commands	RI0,minTP	
Temperature	5	
Recorder size	2 * 1GB	

Consequences of the sampling parameters

First and last bin range		1.41	15.76
Battery usage			440Wh
Standard deviation			1.08
Storage space required			113MB
Set the ADCP clock	LT-x	GMT	6 Dec 2008 05:46:38
Run pre-deployment tests			Yes
Name the ADCP deployment			K1012

Deployment details

Switch on date and time	LTx	GMT	6 Dec 2008 05:46:38
Deployment date and time	LTx	GMT	6 Dec 2008 09:45
Deployment Latitude **(do not ignore – if same, please indicate)**			33 40.206
Deployment Longitude **(do not ignore – if same, please indicate)**			18 24.897
Site depth	10m	Deployment depth	10m

Acoustic release (1) serial number and release code		
Acoustic release (2) serial number and release code		
Argos beacon serial number	-	
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)	**K1012**	

30m ADCP.

1. RECOVERY Site Name: Koeberg 30m Date: 4 Dec 2008 .

Instrument type and serial number			RDI	10119
Recovery date and time	LTx	GMT	**08h00 4 Dec 2008**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**	
Switch off date and time	LTx	GMT	23h00 4 Dec 2008	
File size			166MB	
Was the data copied to memory card?			Yx	N

2. **RE-DEPLOYMENT Site Name: Koeberg 30m Date: 6 Dec 2008 .**

Instrument type and serial number (do not ignore – if same, please indicate)	RDI	**10119**
Install a new battery and/or check the voltage		**1*44.9V**
Frequency of unit being used	**600KHz**	
Depth range	**30m**	
Number of bins (calculated automatically)	**69**	
Bin Size (calculated automatically)	**0.5**	
Wave burst duration	**34.16min**	
Time between wave bursts	**60min**	
Pings per ensemble	**250**	
Ensemble interval	**10min**	
Deployment duration	**15 days**	
Transducer depth	**30m**	
Any other commands	**RI0,minTP**	
Temperature	**5**	
Recorder size	**1128MB**	

Consequences of the sampling parameters

First and last bin range			**1.6**	**35.6**
Battery usage				**449Wh**
Standard deviation				**0. 86**
Storage space required				**112MB**
Set the ADCP clock	LT-x	GMT	**5 Dec 2008 21:06:57**	
Run pre-deployment tests				**Yes**
Name the ADCP deployment			**K3112**	

Deployment details

Switch on date and time	LT-x	GMT	**5 Dec 2008 21:06:57**
Deployment date and time	LT-x	GMT	**6 Dec 2008 08:33**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Site depth	30m	Deployment depth	**30m**

Acoustic release (1) serial number and release code		**32385**
Acoustic release (2) serial number and release code		
Argos beacon serial number		
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)	**K3130**	

7.2 RBR-CT LOGGERS RECOVERY AND RE-DEPLOYMENT SHEETS

1. RECOVERY **Site Name: Koeberg 10m** **Date: 4 Dec 2008**

Instrument type and serial number			XR 420	12995
Recovery date and time	LTx	GMT	**08h30 4 Dec 2008**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LT	GMT	4 Dec 2008 19:42:44	
File size			44KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg_012995_10m_04 122008_1944	

2. RE-DEPLOYMENT **Site Name: Koeberg 10m** **Date: 6 Dec 2008**

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12995
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	5 Dec 2008	19:54:30
End of logging (date / time)	7 Jan 2009	12h00
Memory usage		.3%
Battery usage		814mAH

Deployment details

Deployment date and time	LT	GMT	6 Dec 2008 09h45	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Site name			Koeberg 10m	
Site depth			10m	
Deployment depth			10m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			**012995**	

1. RECOVERY Site Name: Koeberg 30m Date: 4 Dec 2008 .

Instrument type and serial number			XR 420	12997
Recovery date and time	LT	GMT	**08h00 4 Dec 2008**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.397**	
Switch off date and time	LT	GMT	4 Dec 2008 20:00:33	
File size			84KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 6 December 2008/RBR_RecoveredData	

2. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 6 Dec 2008

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12997
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	5 Dec 2008	19:56:00
End of logging (date / time)	7 Jan 2008	12h00
Memory usage		.3%
Battery usage		814mAH

Deployment details

Deployment date and time	LT - x	GMT	6 Dec 2008 08h33	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.397**	
Site name			Koeberg 30m	
Site depth			30m	
Deployment depth			30m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			**012997.log**	

7.3 ADCP CONFIGURATION FILES

10m ADCP.

```
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 360.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 133.83 MB (140329440 bytes)
;Power usage         = 440.26 Wh
;Battery usage       = 1.0
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
```

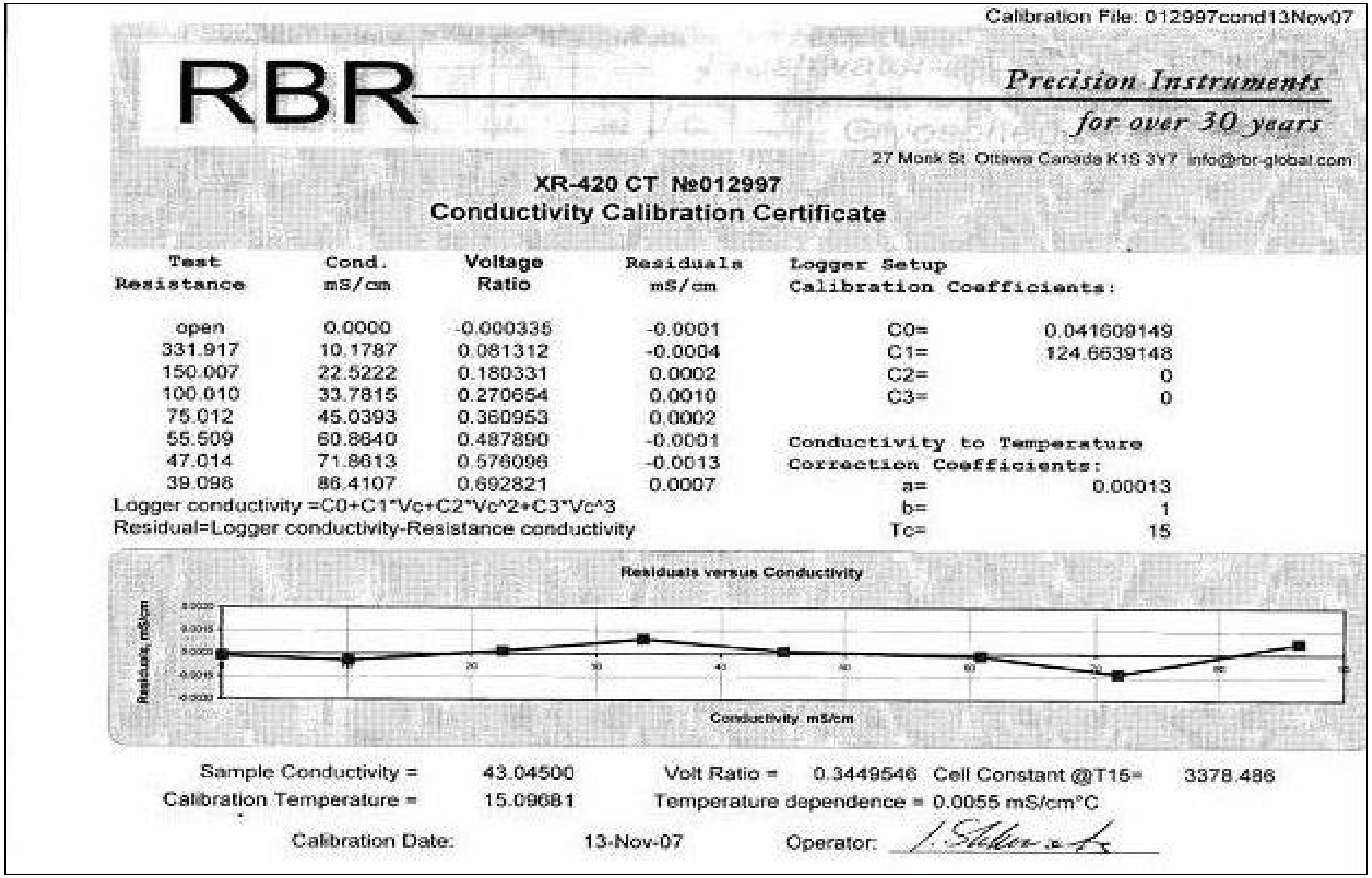
```
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

30m ADCP.

```
CR1
CF11101
EA0
EB0
ED300
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN69
WP250
WS50
WV175
HD111000000
HB5
HP4080
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 360.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1000
;Saved Screen        = 2
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.60 m
;Last cell range     = 35.60 m
;Max range           = 38.22 m
;Standard deviation = 0.86 cm/s
;Ensemble size       = 1534 bytes
;Storage required    = 112.45 MB (117908640 bytes)
;Power usage         = 447.68 Wh
```

```
;Battery usage      = 1.0
;Samples / Wv Burst = 4080
;Min NonDir Wave Per= 2.59 s
;Min Dir Wave Period= 4.31 s
;Bytes / Wave Burst = 318320
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

7.4 RBR-CT CALIBRATION CERTIFICATES



Calibration File: 012997cond13Nov07

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012997
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000335	-0.0001
331.917	10.1787	0.081312	-0.0004
150.007	22.5222	0.180331	0.0002
100.010	33.7815	0.270654	0.0010
75.012	45.0393	0.360953	0.0002
55.509	60.8640	0.487890	-0.0001
47.014	71.8613	0.576096	-0.0013
39.098	86.4107	0.692821	0.0007

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

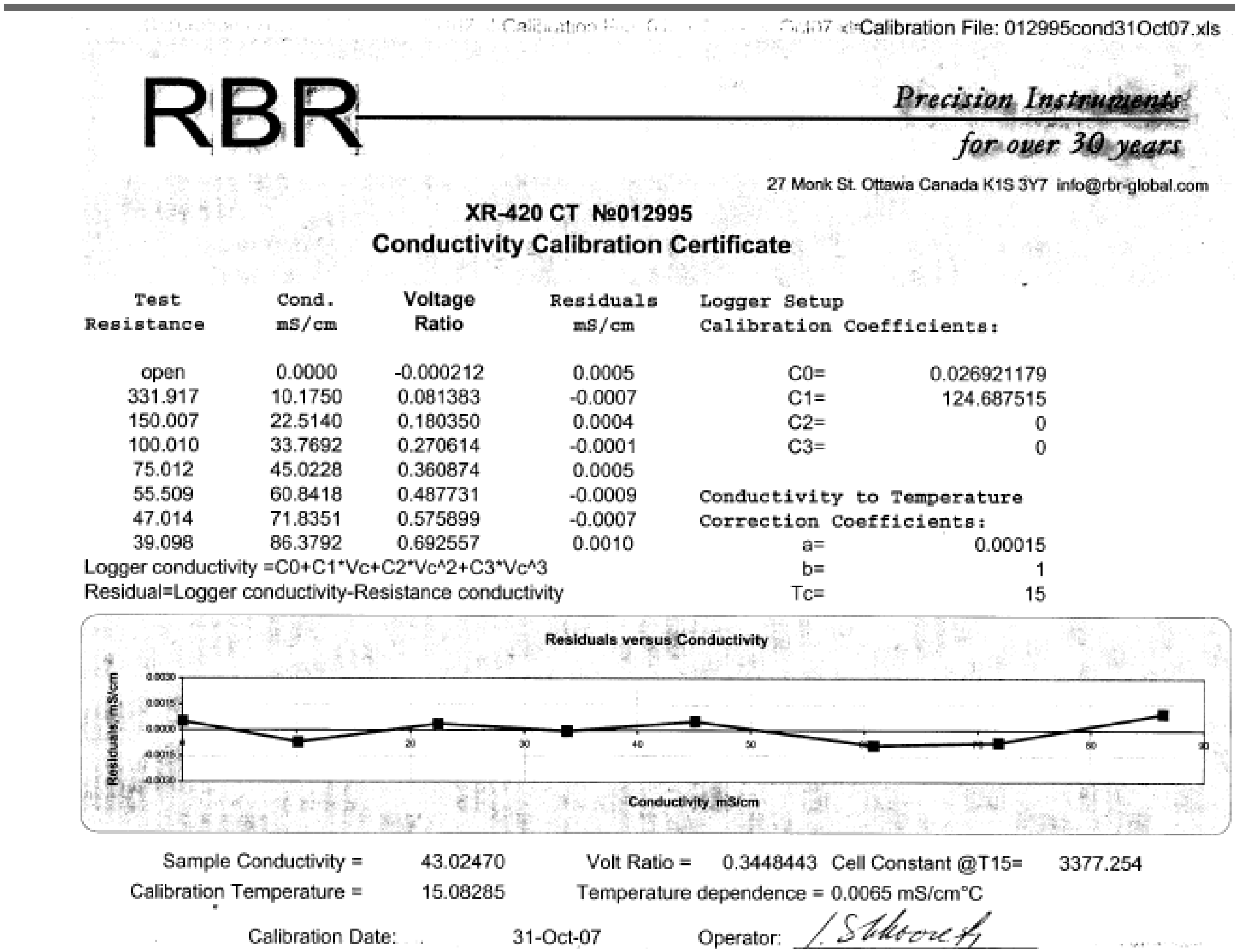
Logger Setup
Calibration Coefficients:

C0= 0.041609149
C1= 124.6639148
C2= 0
C3= 0

Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Sample Conductivity = 43.04500
Volt Ratio = 0.3449546
Cell Constant @T15= 3378.486
Calibration Temperature = 15.09681
Temperature dependence = 0.0055 mS/cm°C
Calibration Date: 13-Nov-07
Operator:



Calibration File: 012995cond31Oct07.xls

RBR Precision Instruments for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012995
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000212	0.0005
331.917	10.1750	0.081383	-0.0007
150.007	22.5140	0.180350	0.0004
100.010	33.7692	0.270614	-0.0001
75.012	45.0228	0.360874	0.0005
55.509	60.8418	0.487731	-0.0009
47.014	71.8351	0.575899	-0.0007
39.098	86.3792	0.692557	0.0010

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.026921179
C1= 124.687515
C2= 0
C3= 0

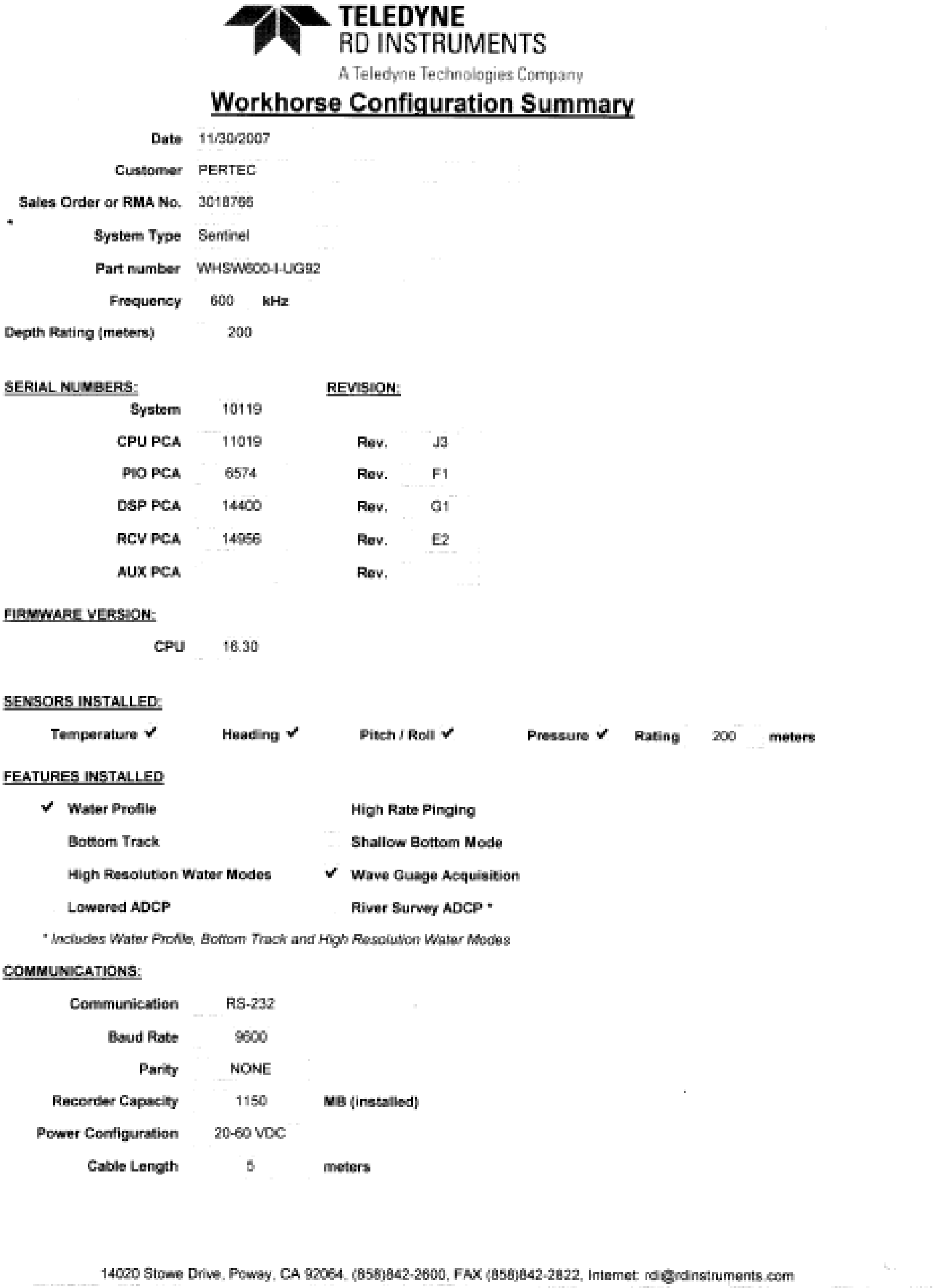
Conductivity to Temperature
Correction Coefficients:

a= 0.00015
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 43.02470
Volt Ratio = 0.3448443
Cell Constant @T15= 3377.254
Calibration Temperature = 15.08285
Temperature dependence = 0.0065 mS/cm°C
Calibration Date: 31-Oct-07
Operator:

7.5 TRDI ADCP CALIBRATION CERTIFICATE



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date	11/30/2007
Customer	PERTEC
Sales Order or RMA No.	3018766
System Type	Sentinel
Part number	WHSW600-I-UG92
Frequency	600 **kHz**
Depth Rating (meters)	200

SERIAL NUMBERS:		**REVISION:**	
System	10119		
CPU PCA	11019	**Rev.**	J3
PIO PCA	6574	**Rev.**	F1
DSP PCA	14400	**Rev.**	G1
RCV PCA	14956	**Rev.**	E2
AUX PCA		**Rev.**	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ **Heading** ✓ **Pitch / Roll** ✓ **Pressure** ✓ **Rating** 200 **meters**

FEATURES INSTALLED

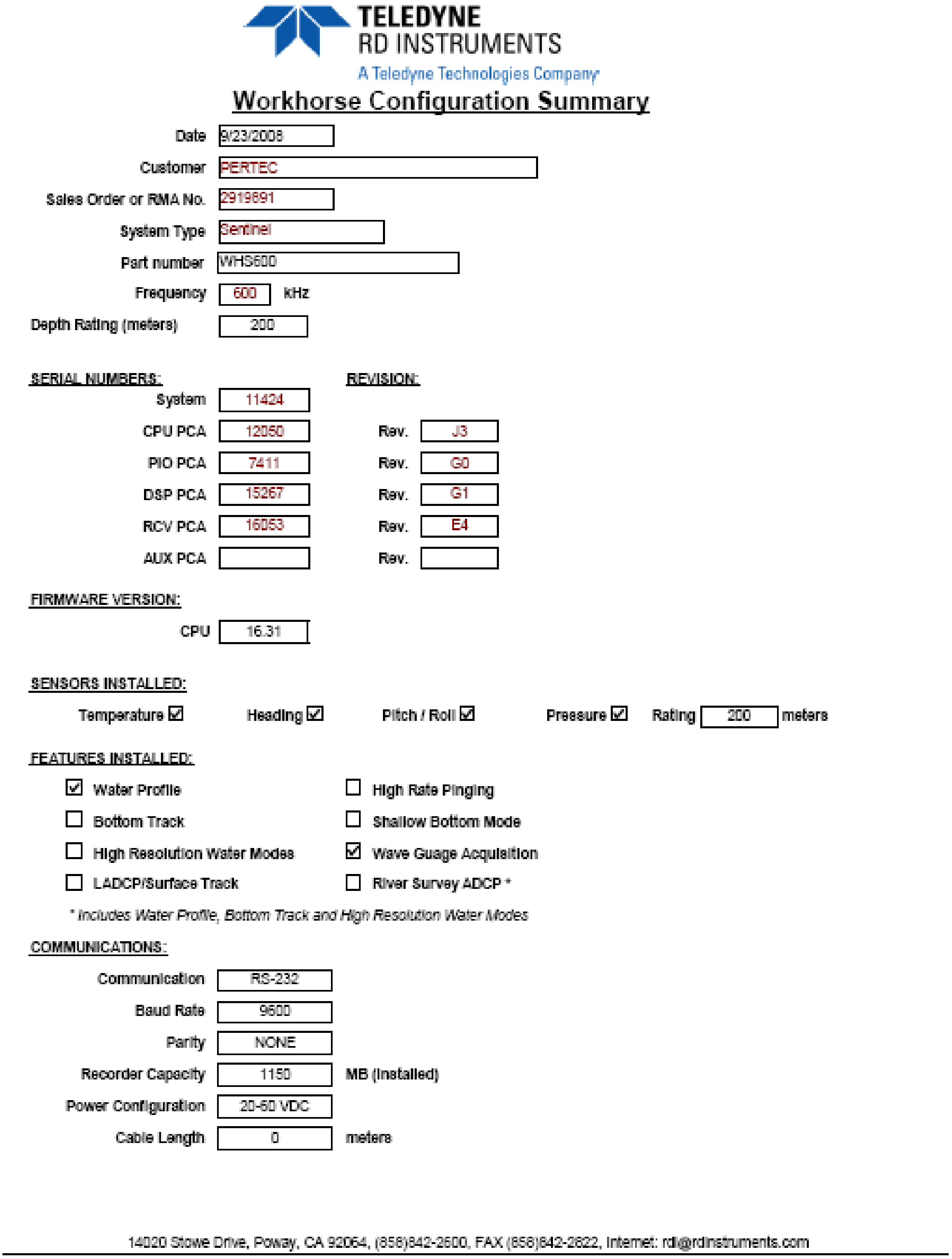
✓ **Water Profile**
Bottom Track
High Resolution Water Modes
Lowered ADCP
High Rate Pinging
Shallow Bottom Mode
✓ **Wave Guage Acquisition**
River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication	RS-232
Baud Rate	9600
Parity	NONE
Recorder Capacity	1150 **MB (installed)**
Power Configuration	20-60 VDC
Cable Length	5 **meters**

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 9/23/2008
Customer PERTEC
Sales Order or RMA No. 2919891
System Type Sentinel
Part number WHS600
Frequency 600 kHz
Depth Rating (meters) 200

SERIAL NUMBERS: / **REVISION:**

System	11424	
CPU PCA	12050	Rev. J3
PIO PCA	7411	Rev. G0
DSP PCA	15267	Rev. G1
RCV PCA	16053	Rev. E4
AUX PCA		Rev.

FIRMWARE VERSION:

CPU 16.31

SENSORS INSTALLED:

Temperature ☑ Heading ☑ Pitch / Roll ☑ Pressure ☑ Rating 200 meters

FEATURES INSTALLED:

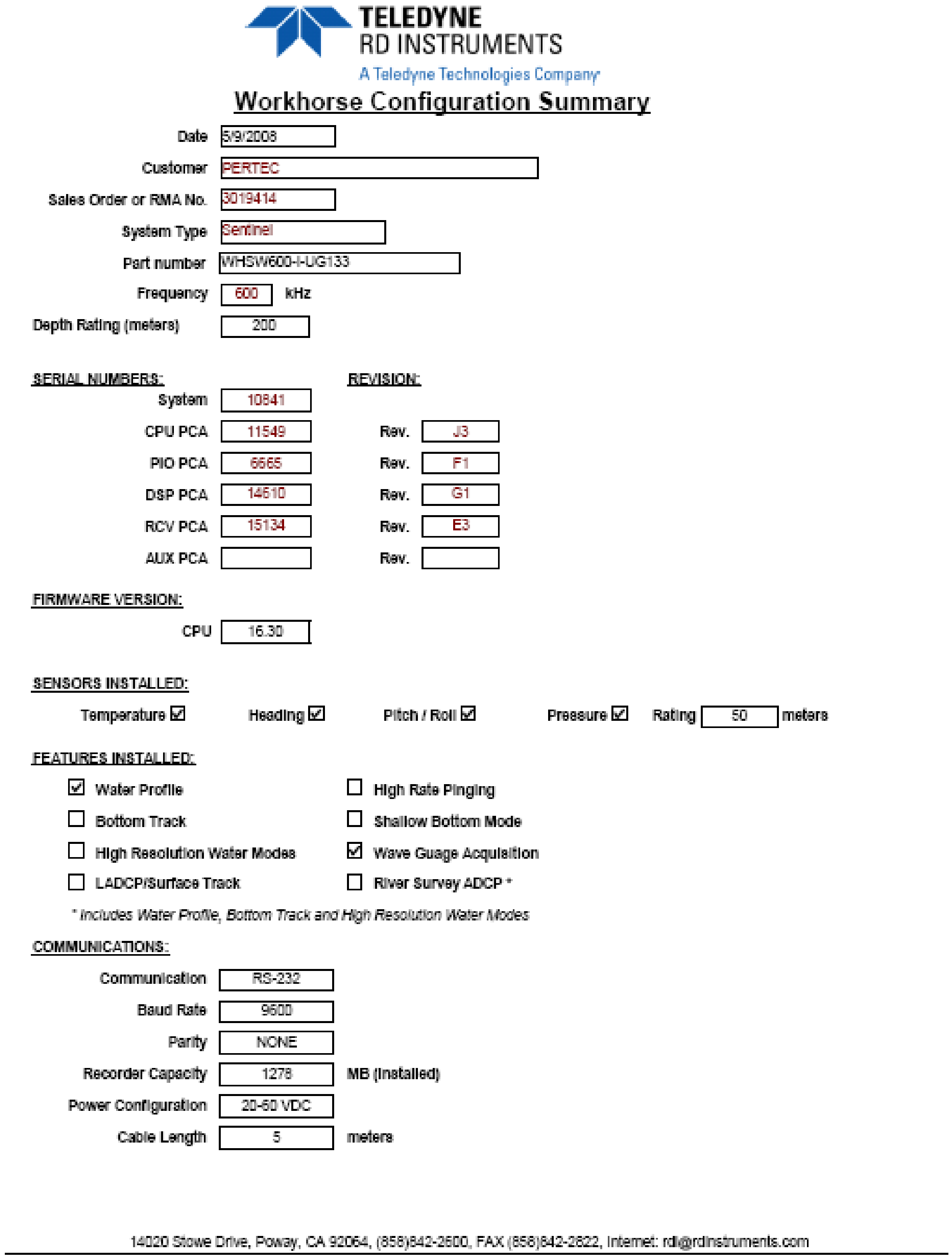
☑ Water Profile
☐ Bottom Track
☐ High Resolution Water Modes
☐ LADCP/Surface Track
☐ High Rate Pinging
☐ Shallow Bottom Mode
☑ Wave Guage Acquisition
☐ River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232
Baud Rate 9600
Parity NONE
Recorder Capacity 1150 MB (Installed)
Power Configuration 20-60 VDC
Cable Length 0 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2622, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date: 5/9/2008
Customer: PERTEC
Sales Order or RMA No.: 3019414
System Type: Sentinel
Part number: WHSW600-I-UG133
Frequency: 600 kHz
Depth Rating (meters): 200

SERIAL NUMBERS:		REVISION:
System	10841	
CPU PCA	11549	Rev. J3
PIO PCA	6665	Rev. F1
DSP PCA	14610	Rev. G1
RCV PCA	15134	Rev. E3
AUX PCA		Rev.

FIRMWARE VERSION:

CPU: 16.30

SENSORS INSTALLED:

Temperature ☑ Heading ☑ Pitch / Roll ☑ Pressure ☑ Rating: 50 meters

FEATURES INSTALLED:

- ☑ Water Profile
- ☐ Bottom Track
- ☐ High Resolution Water Modes
- ☐ LADCP/Surface Track
- ☐ High Rate Pinging
- ☐ Shallow Bottom Mode
- ☑ Wave Guage Acquisition
- ☐ River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication: RS-232
Baud Rate: 9600
Parity: NONE
Recorder Capacity: 1278 MB (Installed)
Power Configuration: 20-60 VDC
Cable Length: 5 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com

8. REPORTS FROM THE CSIR

The reports from the CSIR are attached as an appendage.

CERTIFICATE OF ANALYSIS

Our ref: H:\USERS\MARLAB\REPORTS\Malr2887

Report Number: MALR2887

18 December 2008

Lwandle Technologies
Gabriel Place
1 Gabriel Road
Plumstead
7800

Attention Craig Matthysen

CHEMICAL ANALYSIS: Water samples (Order No.:)
Samples received: 15/12/08
Analysis completed: 18/12/08

Sample description: Seawater in sealed plastic bottles.

Lab No	**Sample Id**	**Total Suspended Solids in mg/L**
35233	**K 1**	*4*
35234	**K 2**	*<2*
35235	**K 3**	*4*
35236	**K 4**	*5*
35237	**K 5**	*7*
35238	**K 6**	*4*
35239	**K 7**	*4*
35240	**K 8**	*5*
35241	**K 9**	*4*
35242	**K 10**	*10*
35243	**K 11**	*14*

Andrew Pascall	Sebastian Brown
MARINE ANALYTICAL SERVICES	MARINE ANALYTICAL SERVICES
Laboratory Manager	Deputy Laboratory Manager

- Method not included in the scope of accreditation.

LWANDLE TECHNOLOGIES (PTY) LTD

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT SIX

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

11 February 2009

Job No: LT-JOB-50

LWANDLE TECHNOLOGIES (PTY) LTD

Directors: C.P. Matthysen, M. Majodina, B.J. Spolander

Unit 13/15 Constantia Business Park, Princess Vlei Road,
Diep River, 7800, South Africa

Co Reg. No. 2003/015524/07

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 6 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary for 10m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-9.0	98.38	0.6385	0.0930	0.0860	0.0109	52.50
-8.7	98.38	0.6316	0.0969	0.0889	0.0131	51.64
-8.3	98.38	0.6254	0.1004	0.0914	0.0149	51.07
-8.0	98.38	0.6171	0.1033	0.0933	0.0163	52.08
-7.6	98.40	0.5940	0.1067	0.0950	0.0183	51.74
-7.3	98.38	0.6105	0.1095	0.0968	0.0201	50.51
-6.9	98.38	0.6087	0.1123	0.0988	0.0213	48.10
-6.6	98.36	0.6128	0.1154	0.0998	0.0223	46.65
-6.2	98.42	0.6350	0.1186	0.1016	0.0230	43.87
-5.9	98.38	0.6267	0.1193	0.1016	0.0243	39.93
-5.5	98.38	0.6485	0.1207	0.1005	0.0244	38.81
-5.2	98.40	0.6538	0.1263	0.1065	0.0250	30.49
-4.8	98.42	0.6623	0.1299	0.1085	0.0273	28.36
-4.5	98.40	0.6685	0.1332	0.1103	0.0285	22.92
-4.1	98.44	0.6785	0.1371	0.1127	0.0305	18.47
-3.8	98.42	0.6800	0.1406	0.1149	0.0333	16.07
-3.4	98.44	0.6884	0.1448	0.1177	0.0369	12.67
-3.1	98.42	0.7284	0.1495	0.1207	0.0400	10.36
-2.7	98.42	0.7589	0.1544	0.1232	0.0433	9.11
-2.4	98.42	0.7565	0.1597	0.1256	0.0463	6.86
-2.0	98.36	0.7984	0.1655	0.1282	0.0501	3.89
-1.7	98.42	0.8645	0.1723	0.1329	0.0561	1.49
-1.3	97.17	0.7351	0.1809	0.1342	0.0627	2.04
-1.0	79.51	0.7600	0.1842	0.1257	0.0569	10.55

Table 2 – Waves summary for 10m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	96.12	12.04	0.45	1.51	1.06
Tp (s)	96.12	19.60	2.00	12.15	2.38
Dp (^{o})	96.12	309.73	45.73	249.93	17.55

Table 3 – Current flow summary for 30m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-26.7	98.05	0.1987	0.0546	0.0298	0.0038	33.06
-26.2	98.05	0.2006	0.0578	0.0318	0.0032	52.66
-25.7	98.05	0.3185	0.0605	0.0334	0.0028	60.48
-25.2	98.05	0.3322	0.0632	0.0348	0.0029	74.10
-24.7	98.05	0.2227	0.0650	0.0358	0.0034	83.64
-24.2	98.05	0.2685	0.0671	0.0369	0.0037	82.31
-23.7	98.03	0.2668	0.0691	0.0378	0.0042	83.83
-23.2	98.05	0.3329	0.0707	0.0391	0.0053	83.09
-22.7	98.05	0.3399	0.0722	0.0402	0.0060	79.62
-22.2	98.05	0.3467	0.0748	0.0414	0.0068	76.54
-21.7	98.05	0.4147	0.0769	0.0430	0.0072	75.04
-21.2	98.03	0.4518	0.0791	0.0443	0.0077	71.09
-20.7	98.05	0.4916	0.0819	0.0458	0.0086	65.44
-20.2	98.05	0.5260	0.0847	0.0474	0.0094	60.45
-19.7	98.05	0.5294	0.0878	0.0494	0.0100	55.68
-19.2	98.05	0.5386	0.0909	0.0513	0.0108	48.93
-18.7	98.05	0.5810	0.0939	0.0534	0.0120	42.19
-18.2	98.05	0.5680	0.0970	0.0554	0.0133	38.30
-17.7	98.03	0.5746	0.1000	0.0574	0.0143	32.14
-17.2	98.01	0.5907	0.1032	0.0594	0.0156	26.29
-16.7	98.01	0.5674	0.1060	0.0617	0.0167	21.45
-16.2	98.01	0.6097	0.1091	0.0640	0.0179	16.63
-15.7	98.01	0.6216	0.1122	0.0664	0.0198	11.71
-15.2	97.99	0.6004	0.1149	0.0684	0.0219	7.35
-14.7	98.03	0.5949	0.1176	0.0707	0.0242	4.81
-14.2	98.05	0.5732	0.1204	0.0736	0.0266	1.49
-13.7	98.03	0.5522	0.1231	0.0761	0.0291	358.79
-13.2	98.03	0.5754	0.1254	0.0792	0.0320	356.52
-12.7	98.03	0.5925	0.1277	0.0825	0.0345	353.87
-12.2	98.03	0.6260	0.1302	0.0856	0.0368	351.27
-11.7	98.01	0.6187	0.1324	0.0886	0.0393	348.88
-11.2	98.03	0.6165	0.1340	0.0918	0.0422	346.32
-10.7	98.01	0.6255	0.1360	0.0945	0.0448	343.81
-10.2	98.03	0.5917	0.1375	0.0978	0.0477	341.45
-9.7	98.01	0.5974	0.1399	0.1008	0.0513	340.29
-9.2	98.03	0.6071	0.1421	0.1036	0.0544	339.04
-8.7	98.03	0.6209	0.1445	0.1063	0.0575	338.45
-8.2	98.03	0.6421	0.1471	0.1091	0.0607	337.56
-7.7	98.03	0.6216	0.1501	0.1113	0.0632	336.84
-7.2	98.03	0.6210	0.1537	0.1131	0.0661	336.66
-6.7	98.03	0.6340	0.1573	0.1151	0.0684	336.07
-6.2	98.03	0.6372	0.1610	0.1168	0.0708	335.76

-5.7	98.03	0.6564	0.1647	0.1186	0.0731	335.07
-5.2	98.03	0.6560	0.1681	0.1206	0.0756	335.30
-4.7	98.03	0.6610	0.1719	0.1221	0.0777	336.01
-4.2	98.05	0.6714	0.1748	0.1232	0.0789	339.07
-3.7	98.05	0.6580	0.1752	0.1239	0.0812	336.33
-3.2	97.56	0.6760	0.1767	0.1234	0.0867	332.05
-2.7	97.32	0.6577	0.1872	0.1217	0.0897	340.37
-2.2	90.99	0.8366	0.1950	0.1210	0.0938	352.94

Table 4 – Waves summary for 30m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	95.79	4.98	0.46	1.41	0.74
Tp (s)	95.79	19.50	2.70	11.34	2.36
Dp (^{o})	95.79	316.73	160.73	239.09	16.25

Table 5 – Water temperature and salinity summary for 10m RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100.00	12.64	18.81	9.51
Conductivity	100.00	35.62	45.95	19.74
Salinity (psu)	100.00	30.28	34.88	16.98

Table 6 – Water temperature and salinity summary for 30m RBR logger

Parameter	Data Return (%)	Mean	Max	Min
Temperature (^{o}C)	100.00	10.60	17.94	9.24
Conductivity	100.00	38.34	45.61	34.92
Salinity (psu)	100.00	34.66	34.94	32.09

1.1 DATA RETURN FOR KOEBERG SITE.

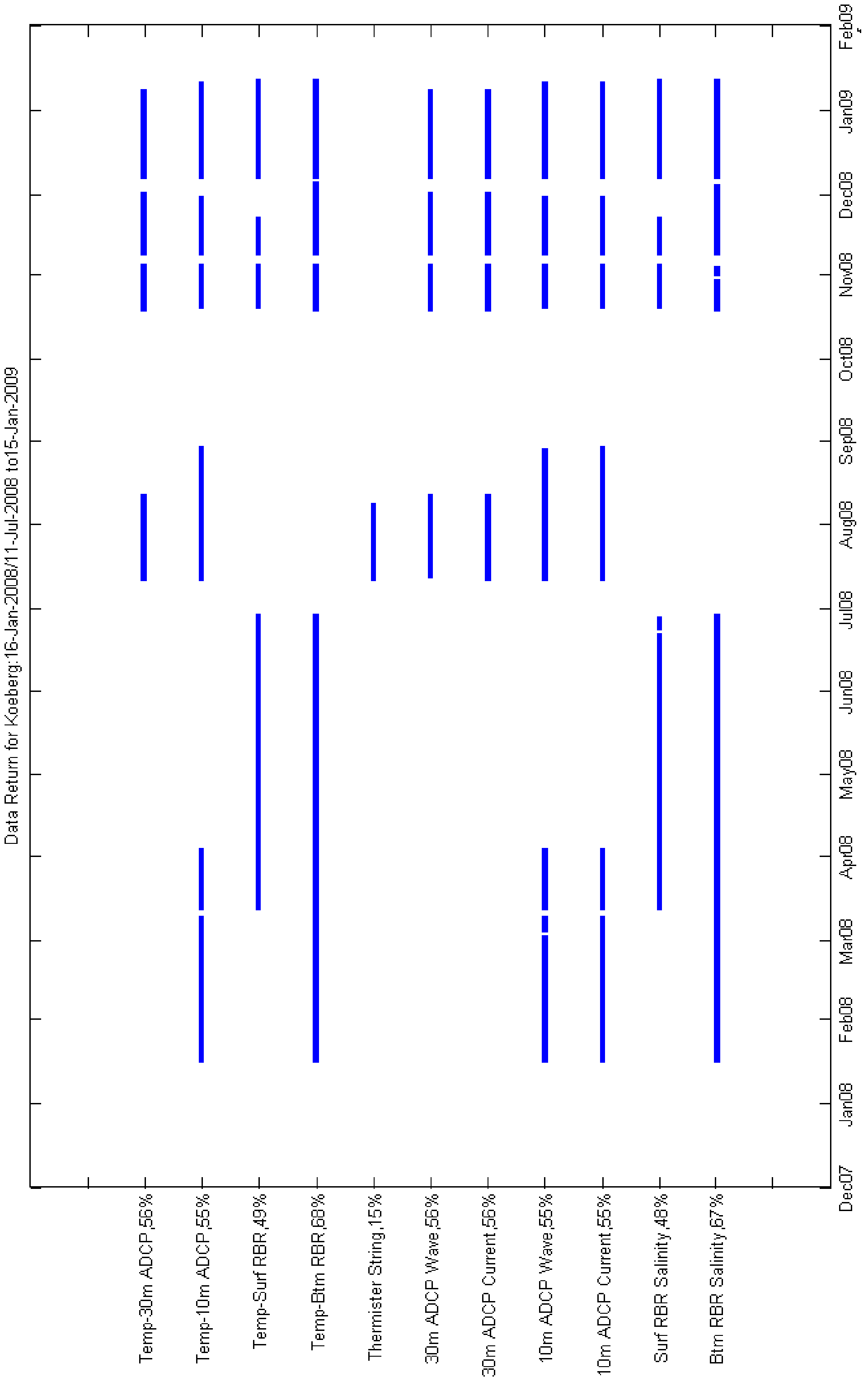


Figure 1: An indication of the data return (%) at the Koeberg site since the beginning of the project (Jan 16th 2008; July 11th 2008 for 30m ADCP and Thermister String). A break down of the temperature (Temp) return from all available instruments is given in the top 5 bars.

2. INTRODUCTION

2.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period December 6th 2008 - January 11th 2009 (Period 6). Service of the instruments was undertaken twice: December 18 – 19th 2008 and January 11 – 15th 2009.

2.2 EQUIPMENT LIST

Lwandle provided the equipment as listed in Table 7 for the Koeberg site.

Table 7 – List of equipment provided.

Item	Operational (on site)	Spare (for whole project)
TRDI 600kHz ADCP	2	1
RBR XR420 CT logger	2	1
RBR Thermister String	0	0

2.3 MEASUREMENT LOCATION

The deployment locations of the moorings are recorded in Table 8.

Table 8 – Initial deployment locations.

Instrument	Latitude (°S)	Longitude (°E)
10m ADCP and RBR logger.	33.6701	18.4150
30m ADCP and RBR logger.	33.6757	18.3898

3. OPERATIONS

3.1 SUMMARY OF EVENTS.

December 18th 2008.
Recovery of the 10m and 30m ADCPs as well as the RBR-CT loggers that was attached on the respective frames was undertaken.

December 19th 2008.
Redeployment of all the instruments was successful.

January 11th 2009.
Recovery of the 10m and 30m ADCPs as well as the RBR-CT loggers that was attached on the respective frames was undertaken.

January 15th 2009.
Redeployment of all the instruments was successful.

3.2 INSTRUMENT CONFIGURATIONS

The deployed instrumentation configurations are given in this section and completed deployment / recovery sheets are given as an appendix (Section 7, page 51) to this report.

3.2.1 600kHz ADCP

Table 9 – Instrument configuration for the 10m ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	10841
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.35 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

Table 10 – Instrument configuration for the 30m ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	10119
Wave burst duration	41 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.5 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

3.2.2 RBR XR420 CT LOGGER

Table 11 – Instrument configuration for T&C Mooring Line.

Parameter	Configuration
XR 420 Temperature and Conductivity	s/n 12995 (10m) and s/n 12997 (30m)
Sampling and Averaging	Sample at 1Hz for 1 minute every 10 minutes

3.2.3 Biofouling Mooring

Table 12 – Instrument configuration for Biofouling Mooring Line.

Parameter	Configuration
Biofouling Plates	3 plates (20cmx20cm) at 3m and 3 plates (20cmx20cm) at 8m
Edgetech Acoustic Release	s/n 32385 release code 642102

3.3 RECOVER AND REDEPLOYMENT METHODOLOGY

3.3.1 T&C mooring and Thermister string

The T&C mooring line was deployed by lowering the array down via a rope through the anchor weights. The mooring line is recovered using divers to undo a single shackle that connects the mooring line to the anchor weights. Divers reattach the line onto the weights, after the instruments have been serviced.

The Thermister string is attached to the 30m ADCP frame. The string comprises of four nodes at 30m, 29m, 19m, and 9m below the surface.

3.3.2 ADCP mooring

The ADCP Frame is lowered to the bottom and moved into position by divers, who also attach chain sections that act as anchors. To retrieve the frame divers have to locate the mooring, take off the anchor chains and surface the frame using air lift bags that they attach.

Figure 2 – ADCP frame with 600KHz instrument.

3.3.3 Biofouling mooring

The biofouling mooring line was deployed by lowering the array down via a rope through the anchor weights. Divers would locate the mooring line and retrieve a surface and bottom plate from the line at the required sampling periods.

4. DATA QUALITY CONTROL

4.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

4.1.1 Current processing

- The record was truncated to exclude times pre and post deployment as well for Dec 18 – 19th's service visit when the instruments were out of the water.
- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 16 W (both ADCP sites).
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP's pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of $0.2ms^{-1}$ was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined.
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

4.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 16' W (both ADCP sites).
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

The instruments were recovered, serviced and redeployed on December 18 – 19th 2008.

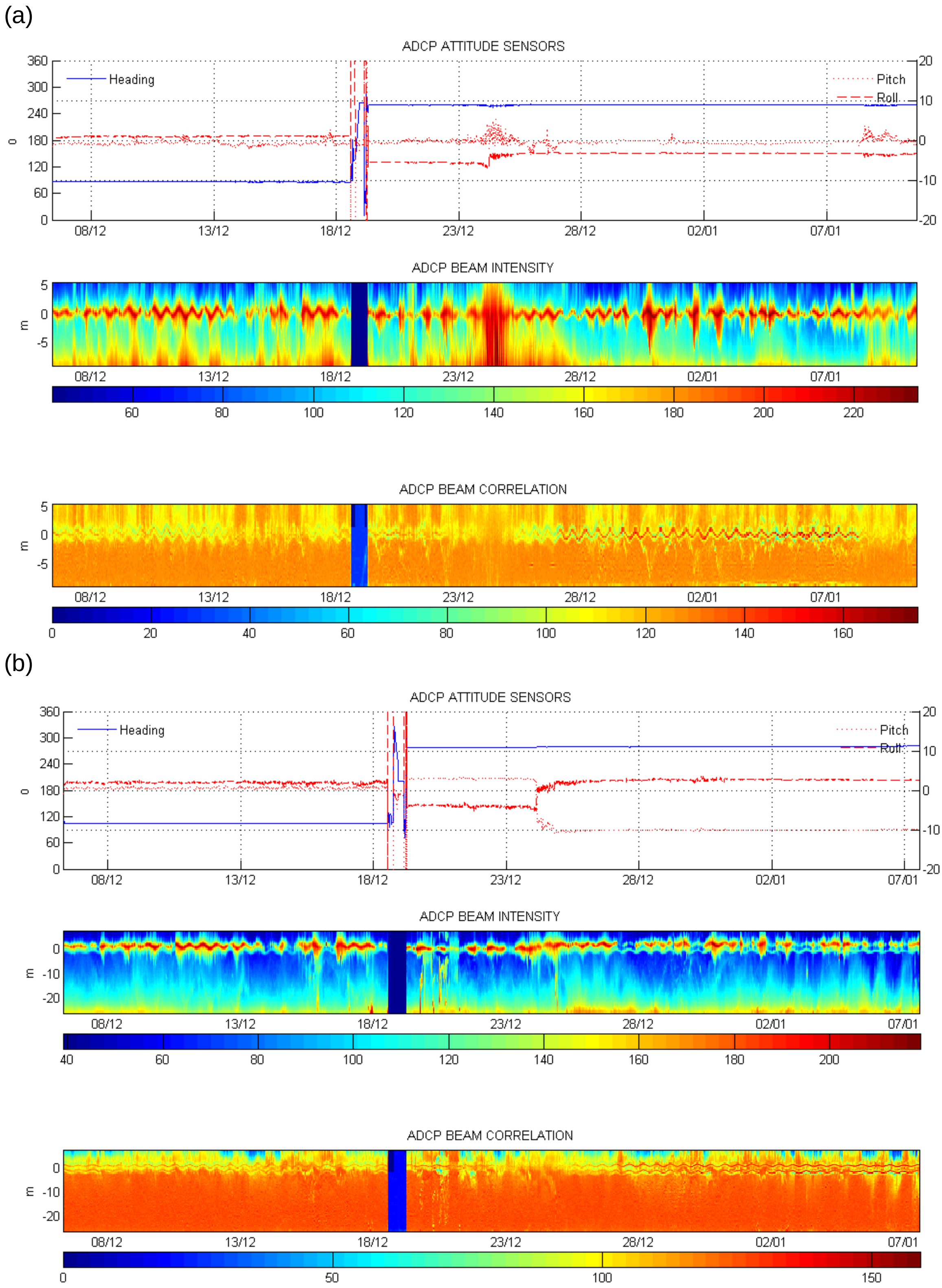


Figure 3: Quality control data from the (a) 10m and (b) 30m ADCPs. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

4.2 RBR-CT LOGGER AND THERMISTER STRING

The conductivity (from the CT-logger) and temperature data were exported directly from the RBR software into Matlab for further processing.

- The record was truncated to exclude times pre and post deployment as well for Dec 18 – 19th's service visit when the instruments were out of the water.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.
- Salinity less than 33 psu were discarded for the 30m instrument.

4.3 BIOFOULING.

The following standard procedure is normally followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates is measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 $CaCO_3$ chips are added.
- Sample bottles are stored upright in the dark.

Recovery of the biofouling plates was not scheduled.

4.4 WATER SAMPLE.

Water samples were not collected.

5. DATA PRESENTATION

All data presented have been subject to the quality control procedures detailed in the previous section. Bad data have been excluded from all plots and calculations.

All plots in this section include a stamp that details the location, depth, time period and number of observations that the plot is based upon. Wherever possible, scaling of parameters has been kept constant throughout this section to facilitate comparison between plots and stations.

5.1 10M ADCP

5.1.1 Current Data

5.1.1.1 <u>Time series plot</u>

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

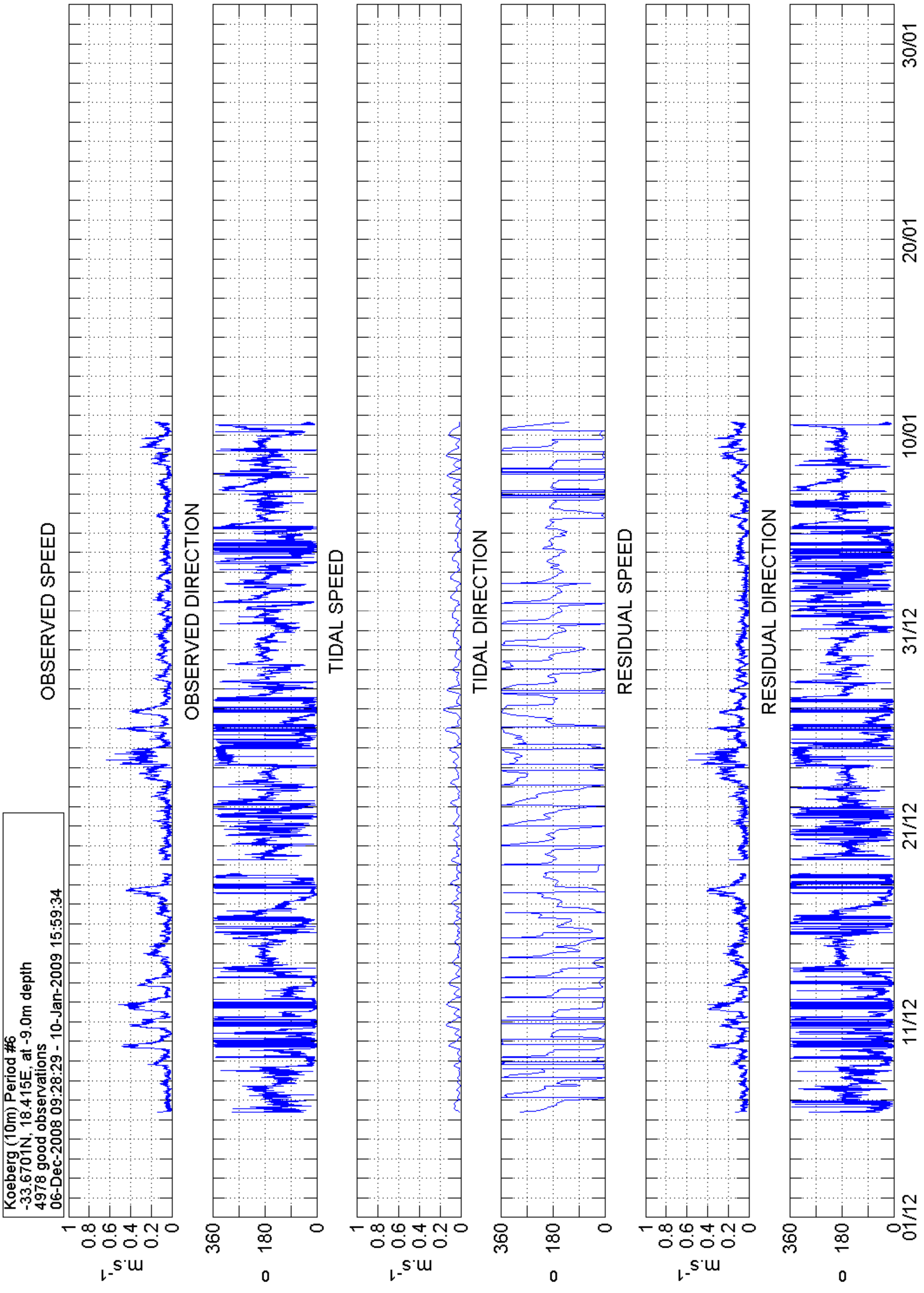


Figure 4: Time series plot of the 10m ADCP's current data at 9.0m.

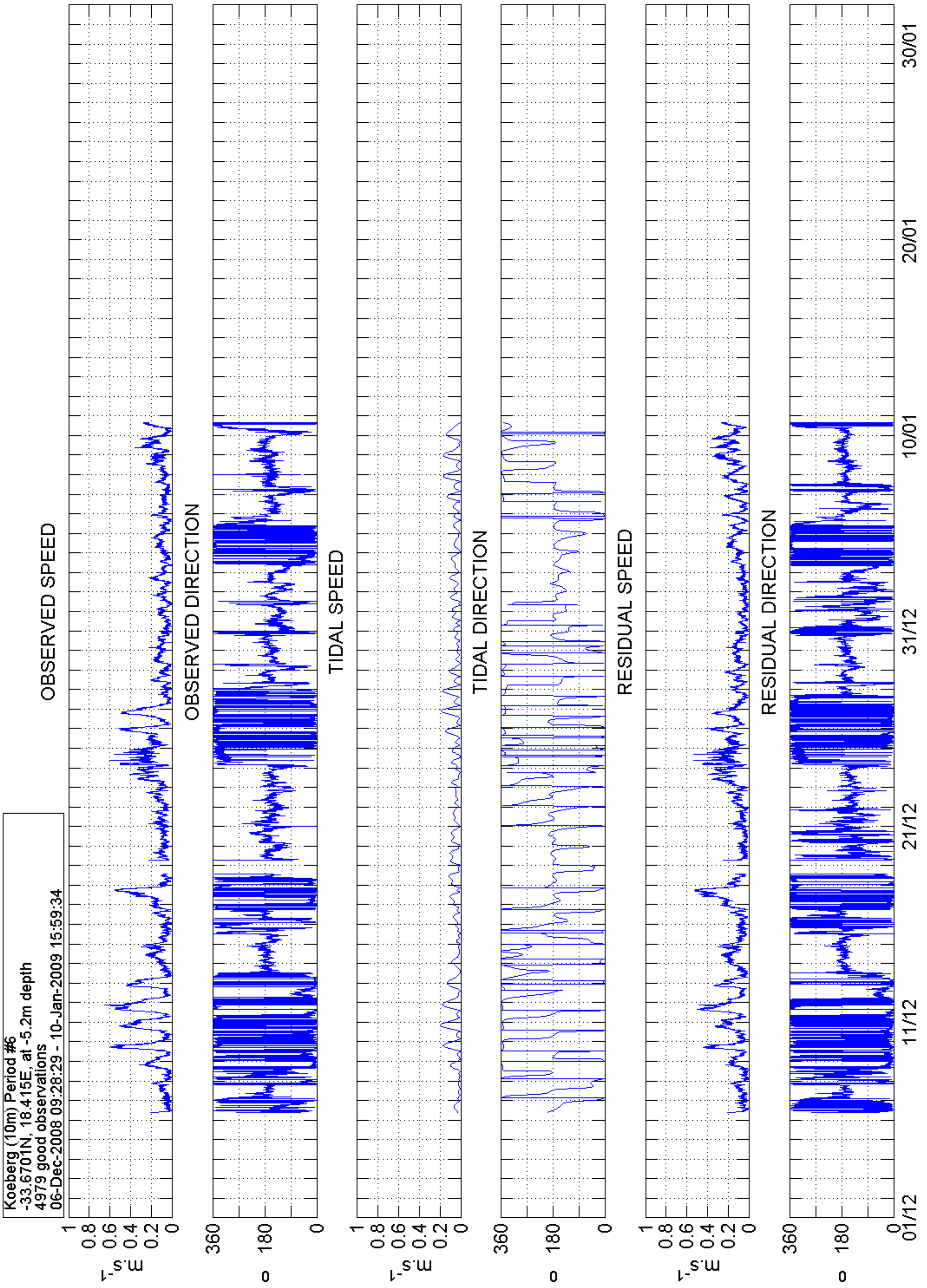


Figure 5: Time series plot of the 10m ADCP's current data at 5.2m.

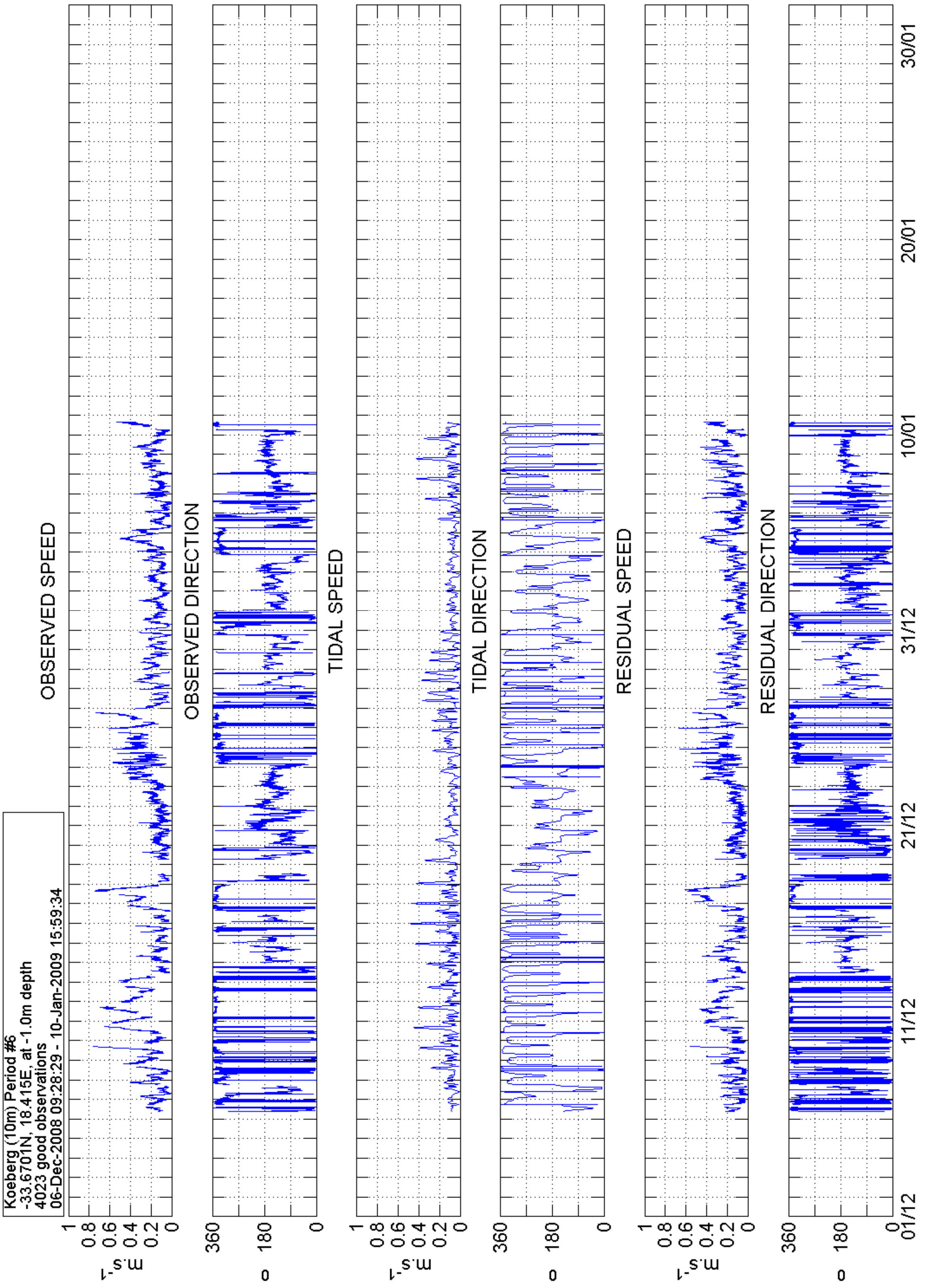


Figure 6: Time series plot of the 10m ADCP's current data at 1.0m.

5.1.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg (10m) Period #6
-33.6701N, 18.415E, at -9.0m depth
4978 good observations
06-Dec-2008 09:28:29 - 10-Jan-2009 15:59:34

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	3.11	3.56	4.46	4.50	6.33	6.75	7.27	8.54	8.18	5.32	2.95	2.55	2.11	1.77	1.73	1.95	71.07
0.1-0.2	1.67	2.37	0.40	0.32	0.24	0.52	0.48	3.25	4.00	2.47	0.50	0.30	0.14	0.18	0.20	0.66	17.72
0.2-0.3	2.25	1.31				0.02	0.16	0.58	0.76	0.26	0.02			0.20	0.42	0.70	6.69
0.3-0.4	1.89	0.34							0.06	0.02			0.02	0.12	0.26	0.48	3.19
0.4-0.5	0.56	0.18												0.04	0.26	0.18	1.23
0.5-0.6	0.02															0.06	0.08
0.6-0.7															0.02		0.02
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	9.50	7.75	4.86	4.82	6.57	7.29	7.91	12.37	13.00	8.08	3.48	2.85	2.27	2.31	2.89	4.04	100.00

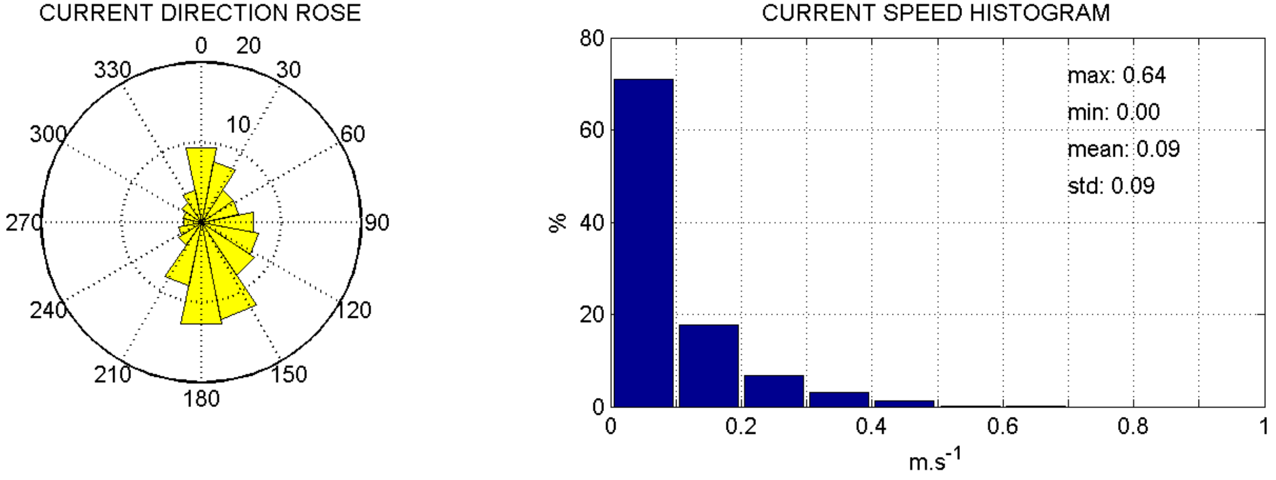
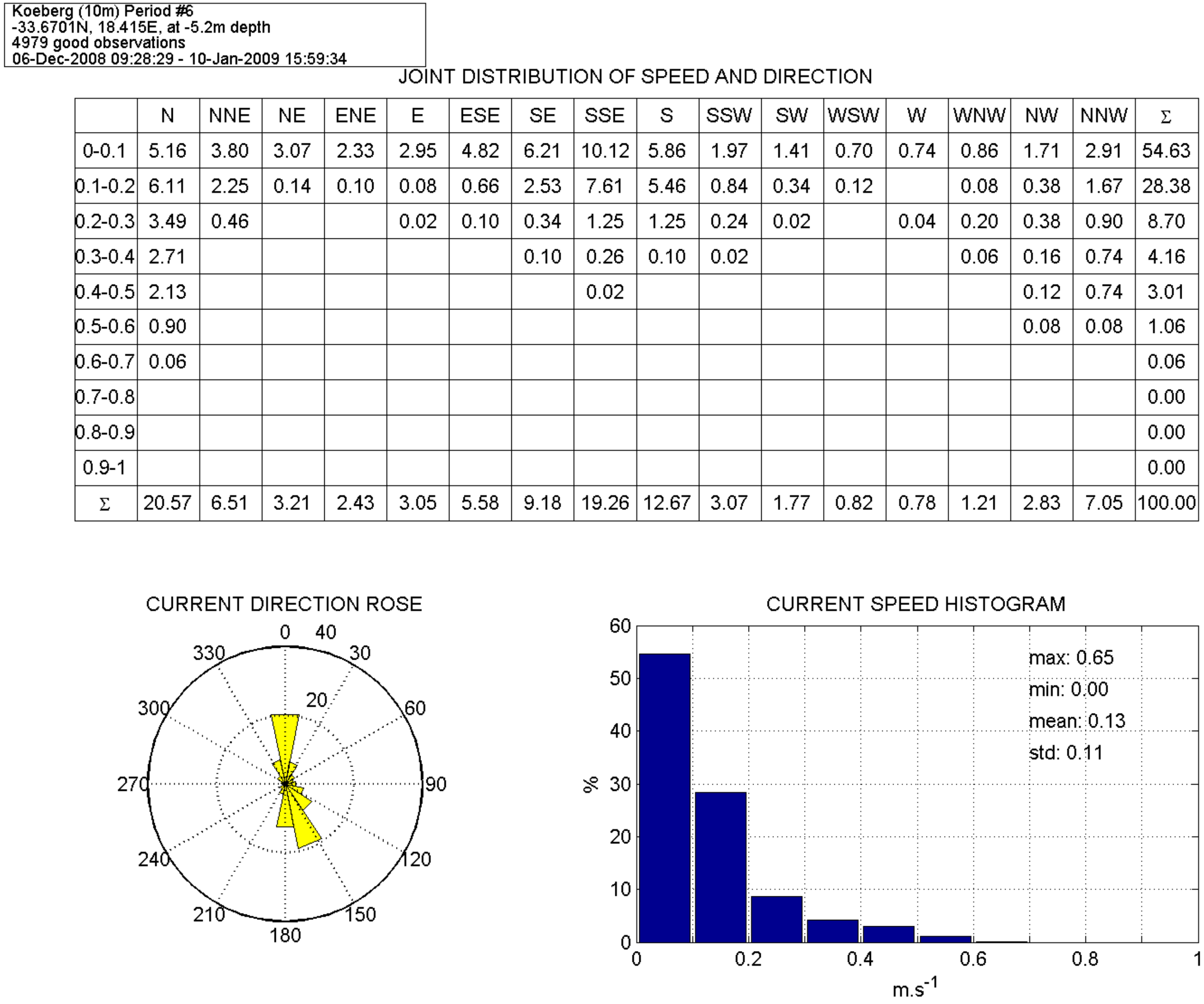


Figure 7: Summary plot of the 10m ADCP's current data at 9.0m.



Koeberg (10m) Period #6
-33.6701N, 18.415E, at -5.2m depth
4979 good observations
06-Dec-2008 09:28:29 - 10-Jan-2009 15:59:34

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	5.16	3.80	3.07	2.33	2.95	4.82	6.21	10.12	5.86	1.97	1.41	0.70	0.74	0.86	1.71	2.91	54.63
0.1-0.2	6.11	2.25	0.14	0.10	0.08	0.66	2.53	7.61	5.46	0.84	0.34	0.12		0.08	0.38	1.67	28.38
0.2-0.3	3.49	0.46			0.02	0.10	0.34	1.25	1.25	0.24	0.02		0.04	0.20	0.38	0.90	8.70
0.3-0.4	2.71						0.10	0.26	0.10	0.02				0.06	0.16	0.74	4.16
0.4-0.5	2.13							0.02							0.12	0.74	3.01
0.5-0.6	0.90														0.08	0.08	1.06
0.6-0.7	0.06																0.06
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	20.57	6.51	3.21	2.43	3.05	5.58	9.18	19.26	12.67	3.07	1.77	0.82	0.78	1.21	2.83	7.05	100.00

Figure 8: Summary plot of the 10m ADCP's current data at 5.2m.

Koeberg (10m) Period #6
-33.6701N, 18.415E, at -1.0m depth
4023 good observations
06-Dec-2008 09:28:29 - 10-Jan-2009 15:59:34

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	1.69	1.44	1.32	1.89	2.56	2.76	3.68	2.91	2.29	1.07	0.42	0.72	0.67	0.77	0.87	2.06	27.12
0.1-0.2	4.13	2.49	1.22	1.89	1.57	3.58	5.52	6.81	4.00	1.12	0.30	0.07	0.12	0.22	2.01	3.65	38.70
0.2-0.3	3.63	0.65	0.12	0.45	0.30	0.85	1.69	2.41	1.59	0.12	0.20		0.05	0.32	1.32	4.28	17.97
0.3-0.4	2.96				0.02	0.05	0.22	0.82	0.17			0.02	0.02	0.10	0.47	4.23	9.10
0.4-0.5	1.52						0.12	0.25							0.12	2.56	4.57
0.5-0.6	0.57														0.07	0.70	1.34
0.6-0.7	0.40															0.60	0.99
0.7-0.8	0.07															0.12	0.20
0.8-0.9																	0.00
0.9-1																	0.00
Σ	14.96	4.57	2.66	4.23	4.45	7.23	11.24	13.20	8.05	2.31	0.92	0.82	0.87	1.42	4.87	18.20	100.00

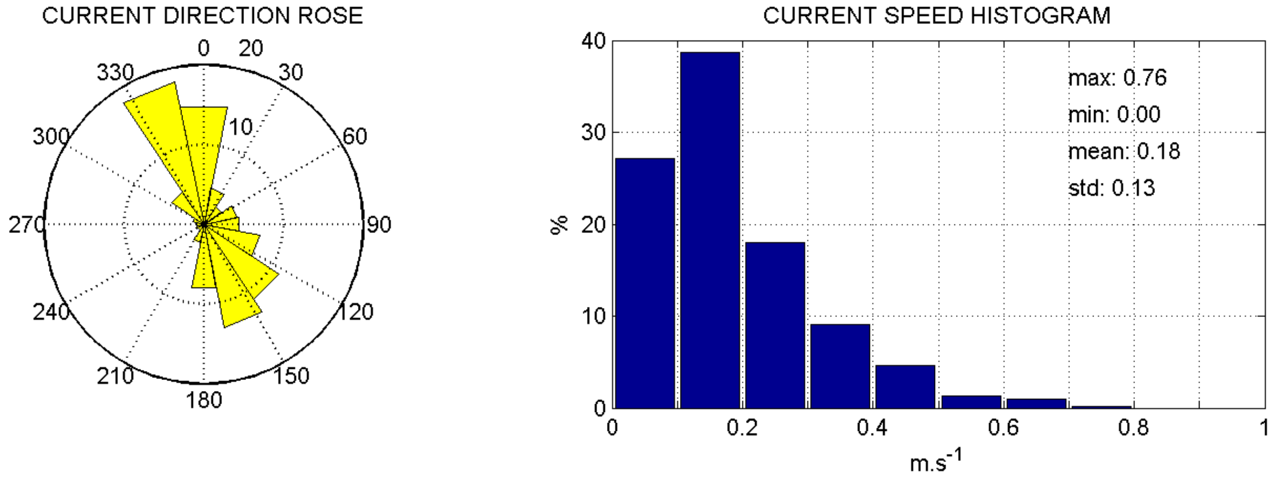


Figure 9: Summary plot of the 10m ADCP's current data at 1.0m.

5.1.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

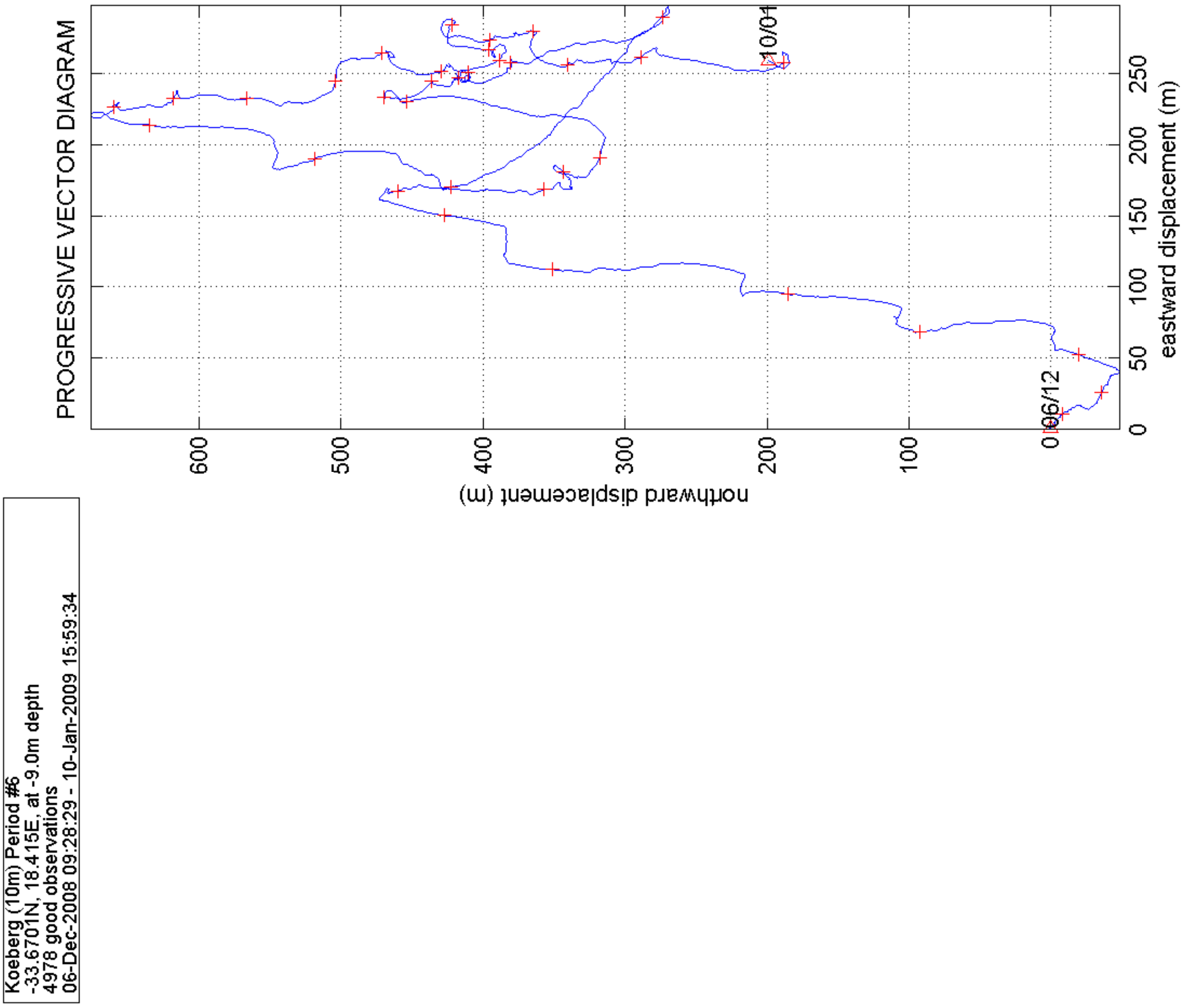


Figure 10: Progressive vector plot of current data at 9.0m.

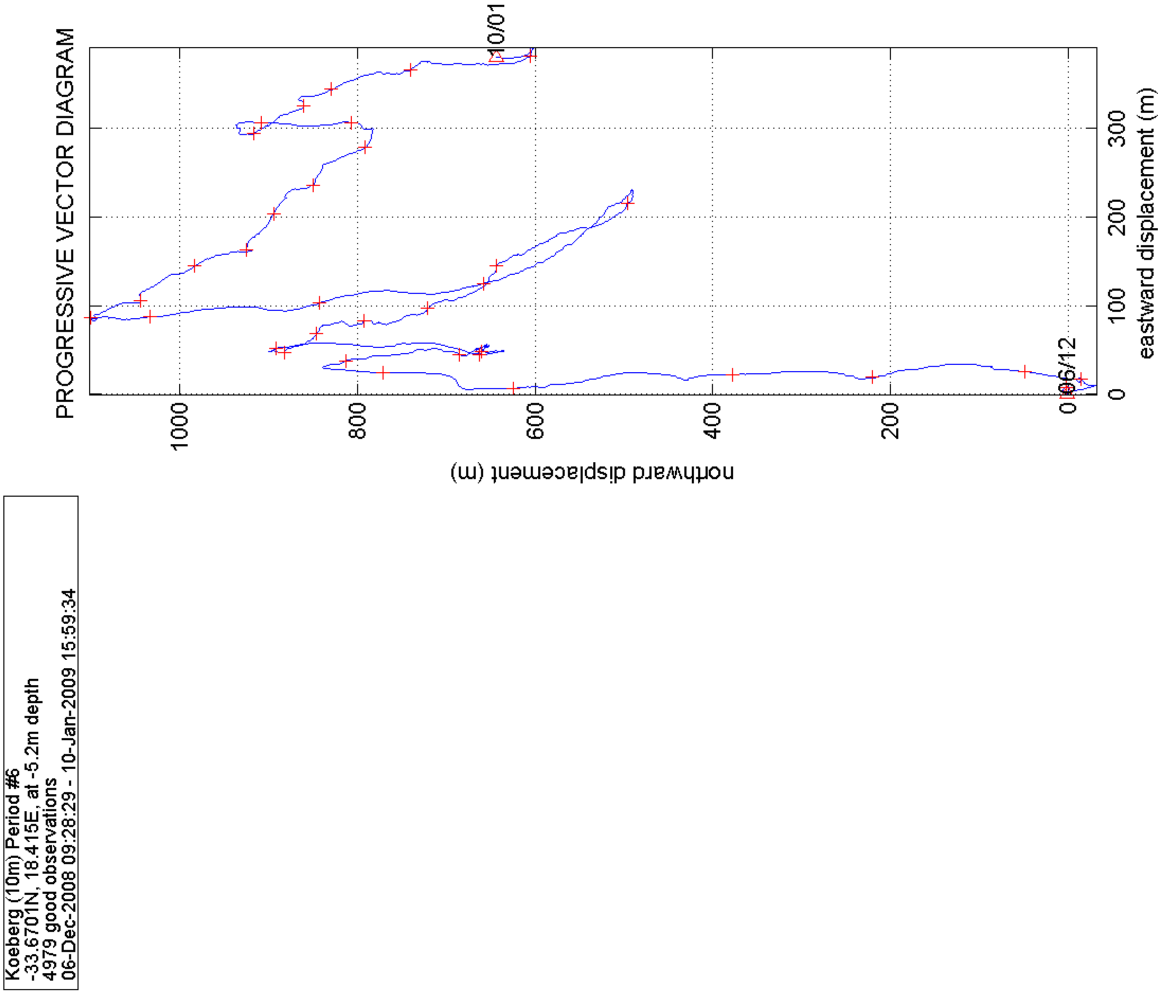


Figure 11: Progressive vector plot of current data at 5.2m.

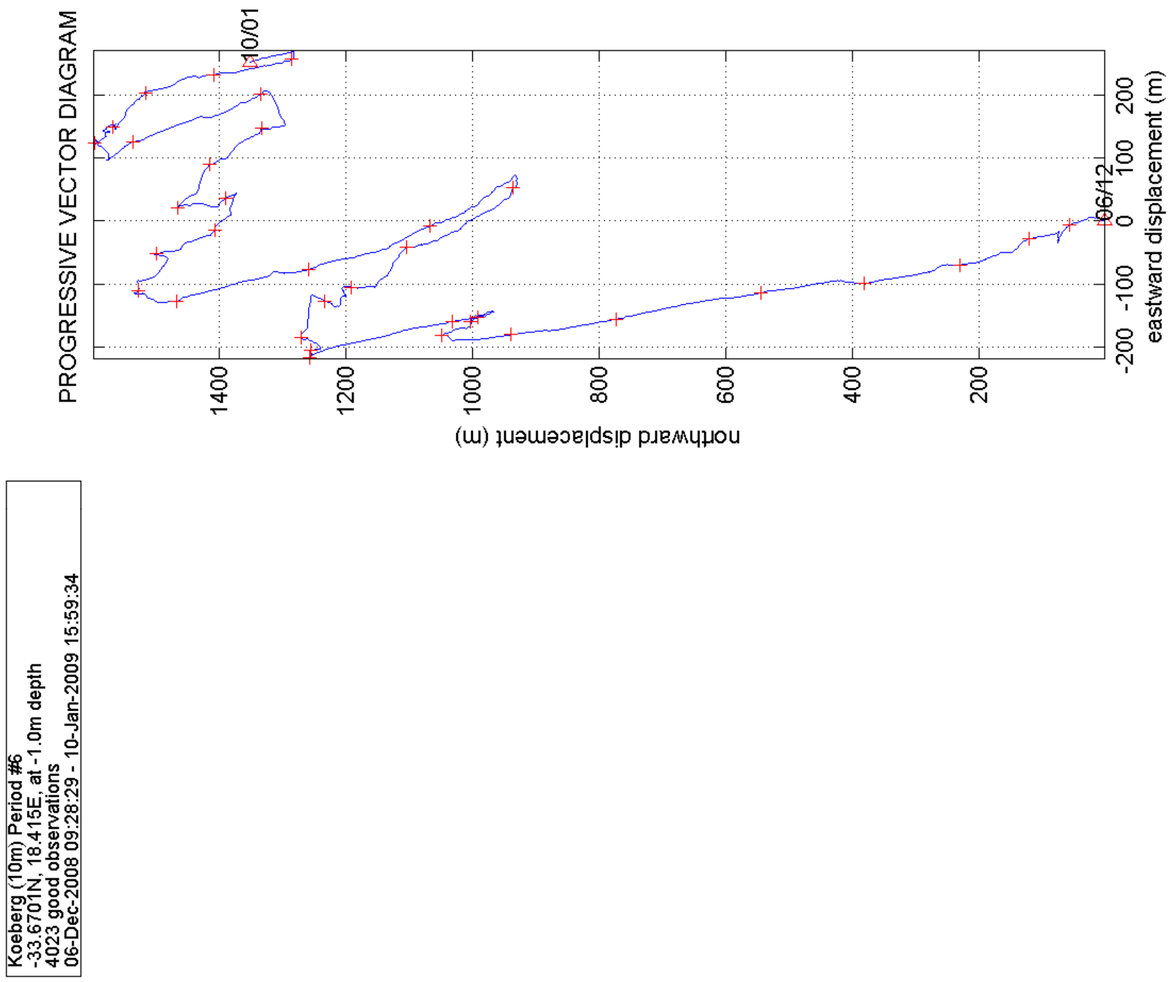


Figure 12: Progressive vector plot of current data at 1.0m.

5.1.2 Wave Data.

5.1.2.1 Hs and Tp summary plot

Figure 13 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.1.2.2 Hs and Dp summary plot

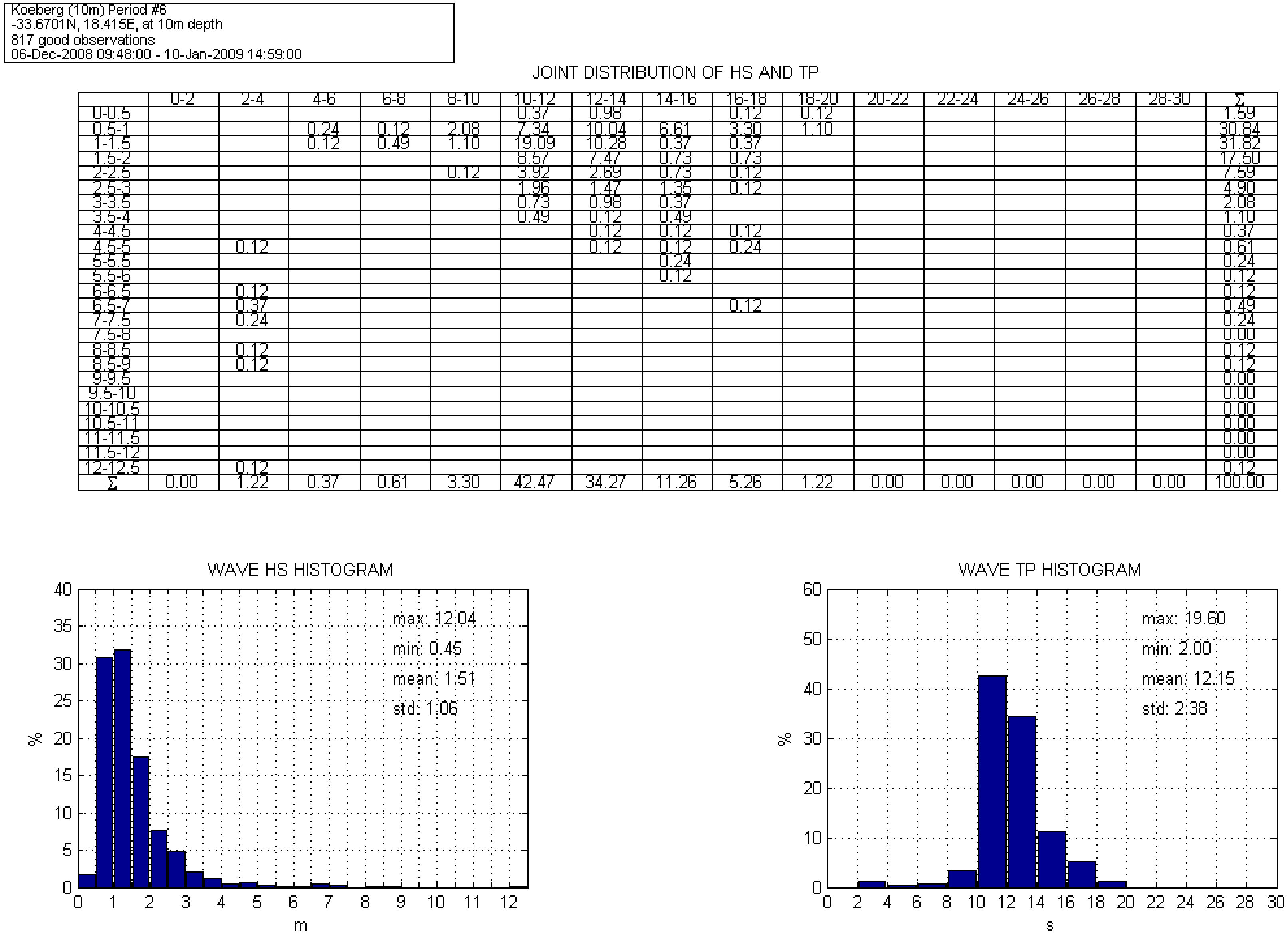
Figure 14 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.1.2.3 Tp and Dp summary plot

Figure 15 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

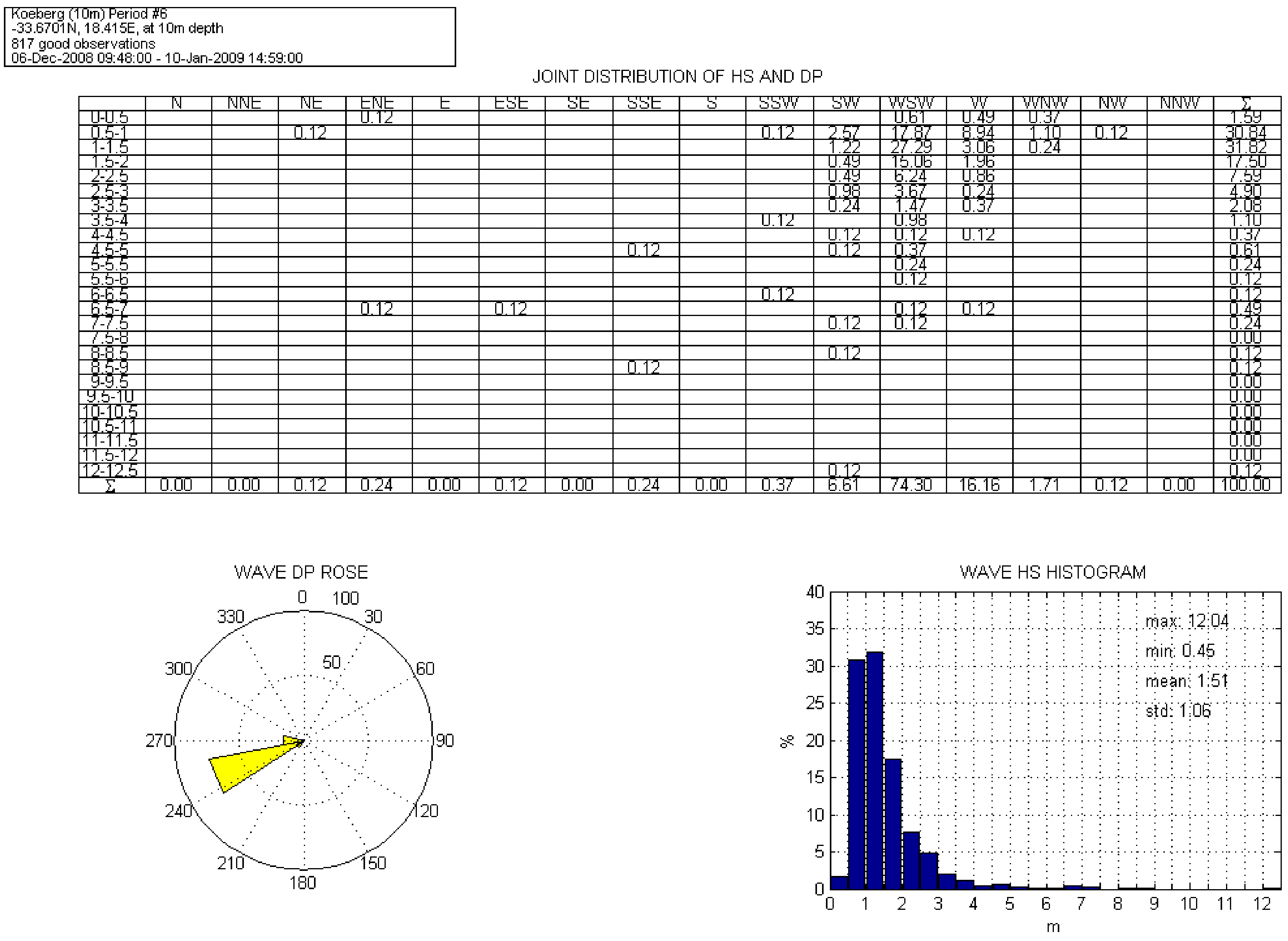


Koeberg (10m) Period #6
-33.6701N, 18.415E, at 10m depth
817 good observations
06-Dec-2008 09:48:00 - 10-Jan-2009 14:59:00

JOINT DISTRIBUTION OF HS AND TP

	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.5						0.37	0.98		0.12	0.12						1.59
0.5-1			0.24	0.12	2.08	7.34	10.04	6.61	3.30	1.10						30.84
1-1.5			0.12	0.49	1.10	19.09	10.28	0.37	0.37							31.82
1.5-2						8.57	7.47	0.73	0.73							17.50
2-2.5					0.12	3.92	2.69	0.73	0.12							7.59
2.5-3						1.96	1.47	1.35	0.12							4.90
3-3.5						0.73	0.98	0.37								2.08
3.5-4						0.49	0.12	0.49								1.10
4-4.5							0.12	0.12	0.12							0.37
4.5-5		0.12					0.12	0.12	0.24							0.61
5-5.5								0.24								0.24
5.5-6								0.12								0.12
6-6.5		0.12														0.12
6.5-7		0.37							0.12							0.49
7-7.5		0.24														0.24
7.5-8																0.00
8-8.5		0.12														0.12
8.5-9		0.12														0.12
9-9.5																0.00
9.5-10																0.00
10-10.5																0.00
10.5-11																0.00
11-11.5																0.00
11.5-12																0.00
12-12.5		0.12														0.12
Σ	0.00	1.22	0.37	0.61	3.30	42.47	34.27	11.26	5.26	1.22	0.00	0.00	0.00	0.00	0.00	100.00

Figure 13: Summary plot of H_s and T_p.



Koeberg (10m) Period #6
-33.6701N, 18.415E, at 10m depth
817 good observations
06-Dec-2008 09:48:00 - 10-Jan-2009 14:59:00

JOINT DISTRIBUTION OF HS AND DP

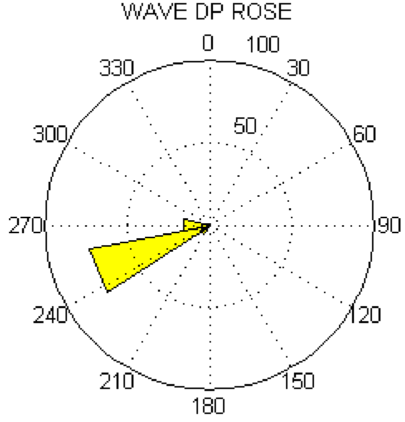
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.5				0.12								0.61	0.49	0.37			1.59
0.5-1			0.12							0.12	2.57	17.87	8.94	1.10	0.12		30.84
1-1.5											1.22	27.29	3.06	0.24			31.82
1.5-2											0.49	15.06	1.96				17.50
2-2.5											0.49	6.24	0.86				7.59
2.5-3											0.98	3.67	0.24				4.90
3-3.5											0.24	1.47	0.37				2.08
3.5-4										0.12		0.98					1.10
4-4.5											0.12	0.12	0.12				0.37
4.5-5								0.12			0.12	0.37					0.61
5-5.5												0.24					0.24
5.5-6												0.12					0.12
6-6.5										0.12							0.12
6.5-7				0.12		0.12						0.12	0.12				0.49
7-7.5											0.12	0.12					0.24
7.5-8																	0.00
8-8.5											0.12						0.12
8.5-9								0.12									0.12
9-9.5																	0.00
9.5-10																	0.00
10-10.5																	0.00
10.5-11																	0.00
11-11.5																	0.00
11.5-12																	0.00
12-12.5											0.12						0.12
Σ	0.00	0.00	0.12	0.24	0.00	0.12	0.00	0.24	0.00	0.37	6.61	74.30	16.16	1.71	0.12	0.00	100.00

Figure 14: Summary plot of H_s and D_p.

Koeberg (10m) Period #6
-33.6701N, 18.415E, at 10m depth
817 good observations
06-Dec-2008 09:48:00 - 10-Jan-2009 14:59:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4				0.12		0.12		0.24		0.12	0.37	0.12	0.12				1.22
4-6										0.12			0.24				0.37
6-8											0.24		0.12	0.24			0.61
8-10											0.86	2.08	0.37				3.30
10-12										0.12	2.57	35.01	4.77				42.47
12-14											1.59	27.29	5.02	0.37			34.27
14-16											0.86	6.98	2.94	0.49			11.26
16-18											0.12	2.69	1.84	0.49	0.12		5.26
18-20			0.12	0.12								0.12	0.73	0.12			1.22
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.12	0.24	0.00	0.12	0.00	0.24	0.00	0.37	6.61	74.30	16.16	1.71	0.12	0.00	100.00



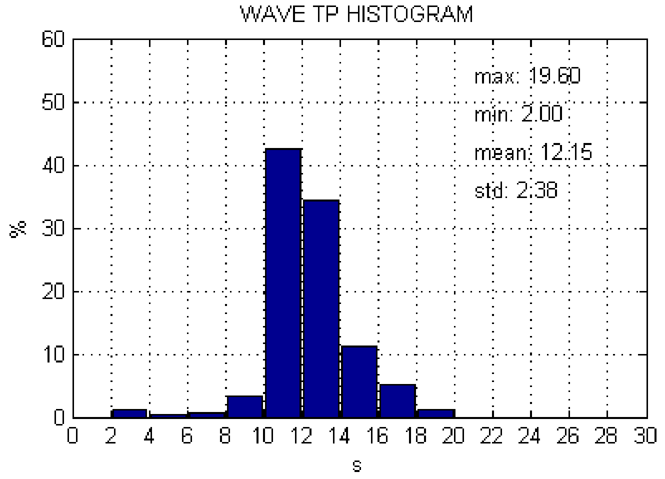


Figure 15: Summary plot of T_p and D_p.

5.1.2.4 Wave spectral plot

Figure 16 displays wave spectral plots for a significant wave event. The time of the spectrum is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

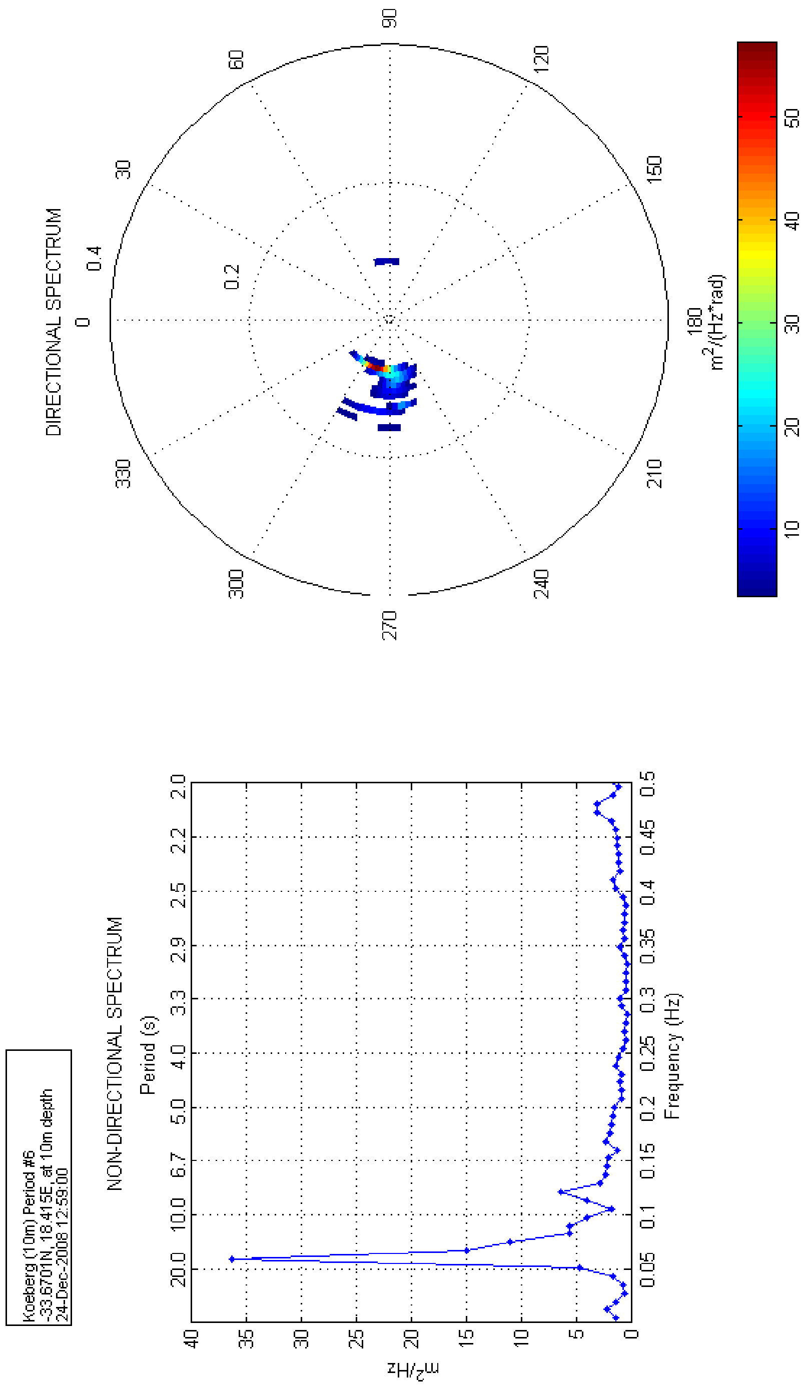


Figure 16: Wave spectra for 24th of December 2008 at 12:59:00.

5.2 30M ADCP

5.2.1 Current Data

5.2.1.1 Time series plot

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

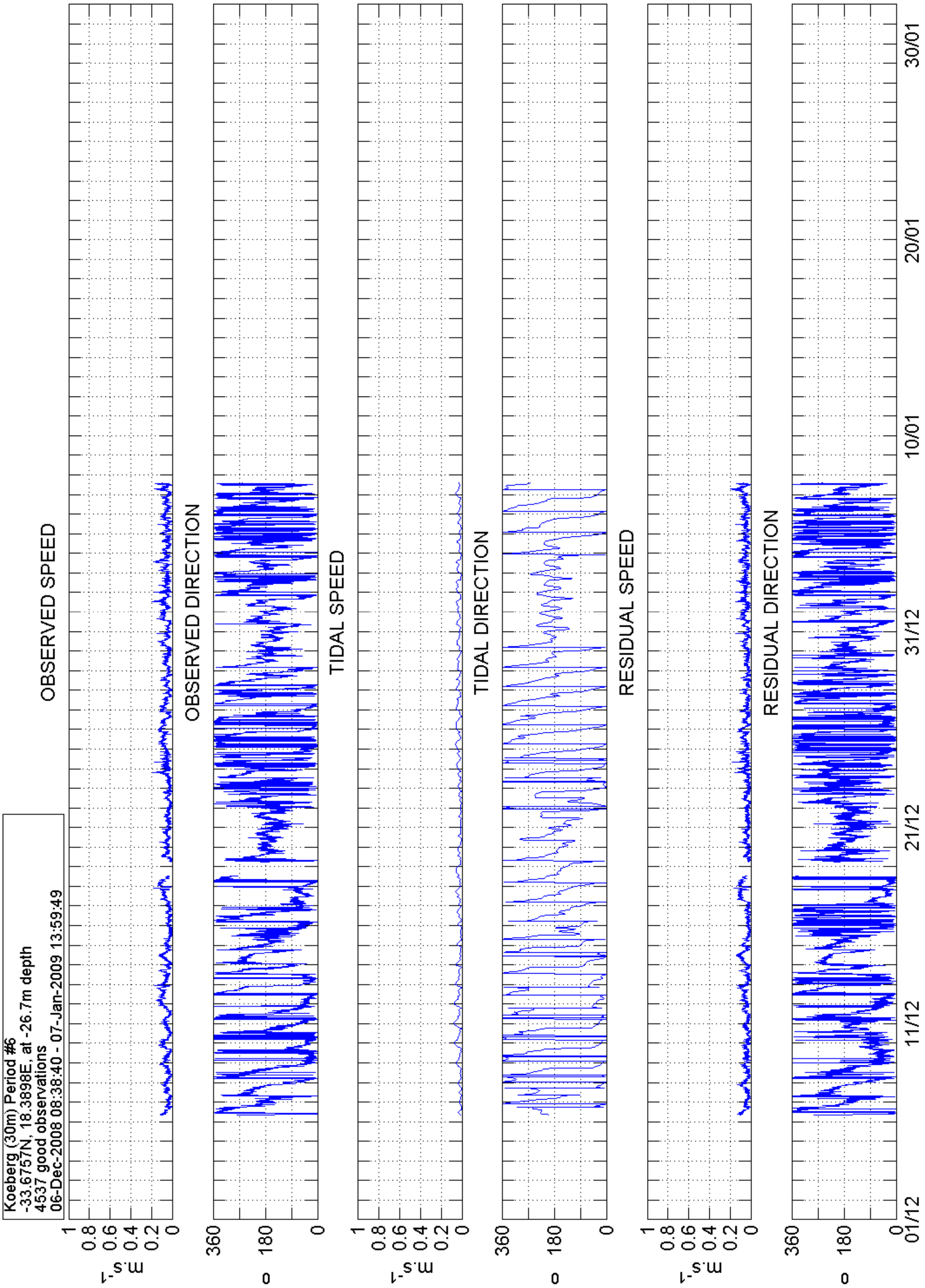


Figure 17: Time series plot of the 30m ADCP's current data at 26.7m.

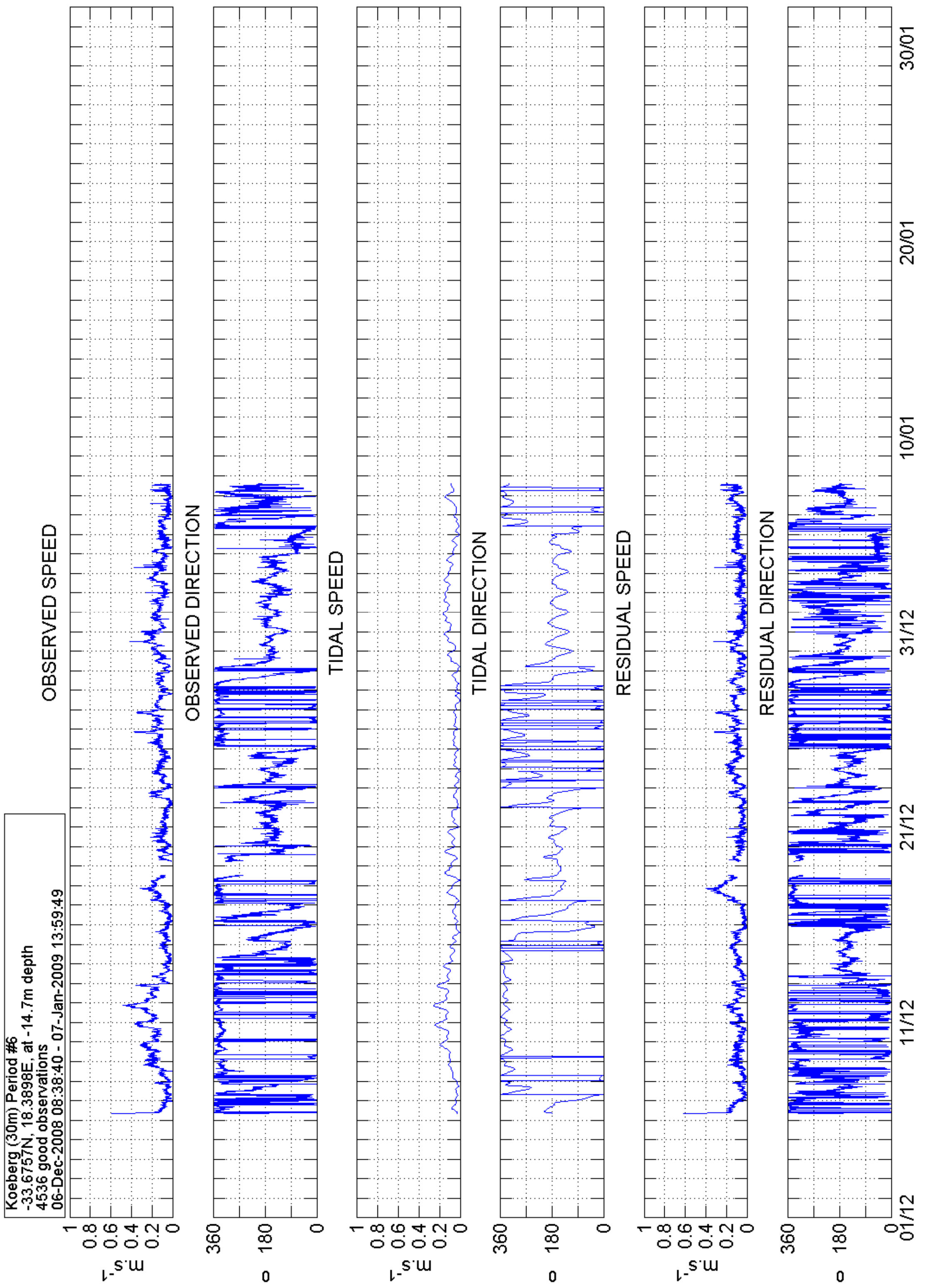


Figure 18: Time series plot of the 30m ADCP’s current data at 14.7m.

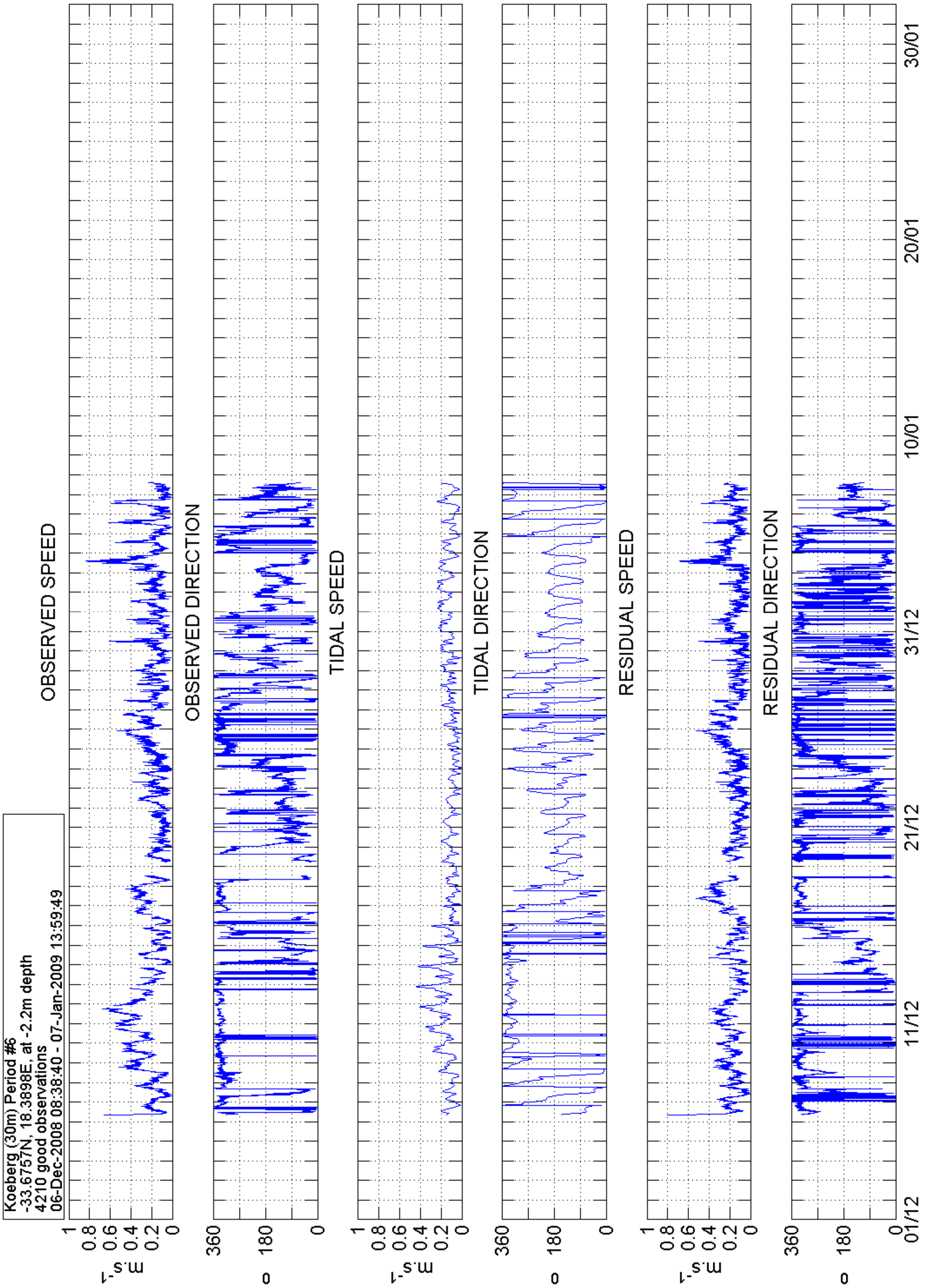


Figure 19: Time series plot of the 30m ADCP's current data at 2.2m.

5.2.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

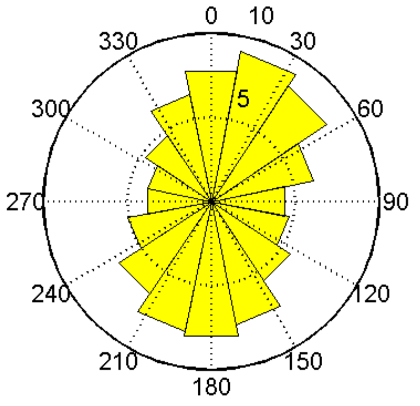
- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.

Koeberg (30m) Period #6
-33.6757N, 18.3898E, at -26.7m depth
4537 good observations
06-Dec-2008 08:38:40 - 07-Jan-2009 13:59:49

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	7.23	7.63	6.88	5.38	4.28	4.61	5.55	7.34	7.76	7.23	5.75	4.30	3.22	3.79	4.61	6.17	91.71
0.1-0.2	0.66	1.43	1.34	0.82	0.18	0.09	0.09	0.11	0.35	0.62	0.86	0.73	0.62	0.04	0.07	0.29	8.29
0.2-0.3																	0.00
0.3-0.4																	0.00
0.4-0.5																	0.00
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	7.89	9.06	8.22	6.19	4.45	4.69	5.64	7.45	8.11	7.85	6.61	5.03	3.84	3.84	4.67	6.46	100.00

CURRENT DIRECTION ROSE



CURRENT SPEED HISTOGRAM

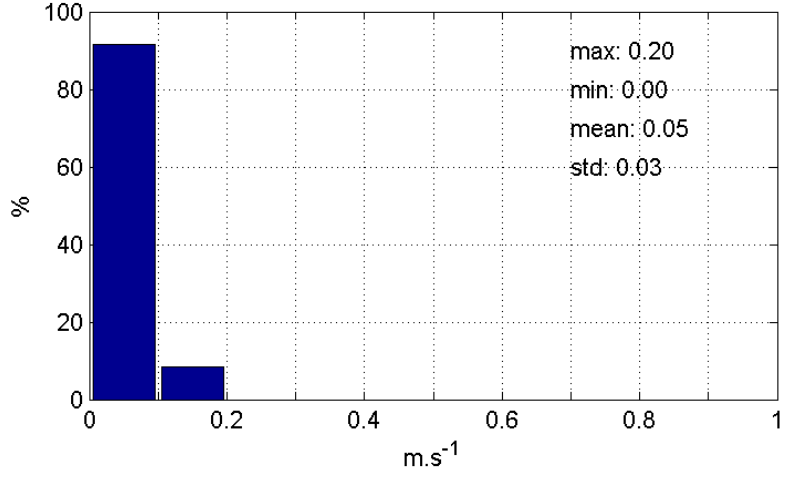


Figure 20: Summary plot of the 30m ADCP's current data at 26.7m.

Koeberg (30m) Period #6
-33.6757N, 18.3898E, at -14.7m depth
4536 good observations
06-Dec-2008 08:38:40 - 07-Jan-2009 13:59:49

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	3.73	2.51	2.45	2.54	2.78	3.31	4.37	5.07	3.97	3.06	1.63	1.37	1.34	2.31	2.40	3.15	45.99
0.1-0.2	7.39	2.07	0.44	1.04	0.77	2.25	3.90	5.58	4.08	1.59	0.49	0.26	0.33	0.60	2.95	9.46	43.19
0.2-0.3	1.70	0.24			0.04	0.11	0.33	1.12	0.46	0.09		0.04			0.62	3.66	8.42
0.3-0.4	0.35					0.02		0.02		0.02					0.02	1.61	2.05
0.4-0.5	0.02							0.02								0.29	0.33
0.5-0.6															0.02		0.02
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	13.18	4.83	2.89	3.57	3.59	5.69	8.60	11.82	8.51	4.76	2.12	1.68	1.68	2.91	6.02	18.17	100.00

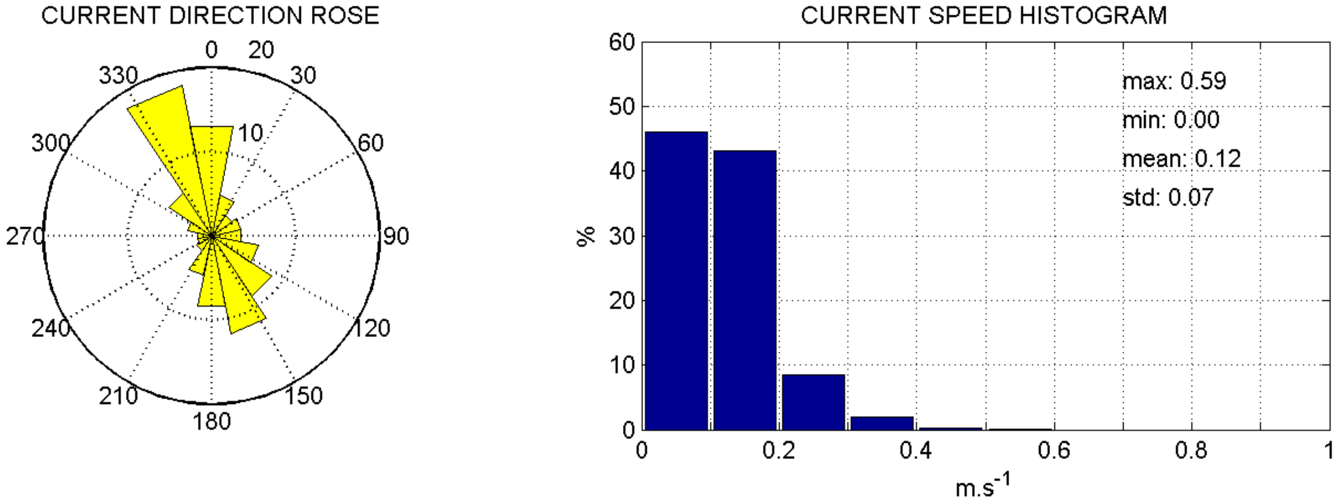


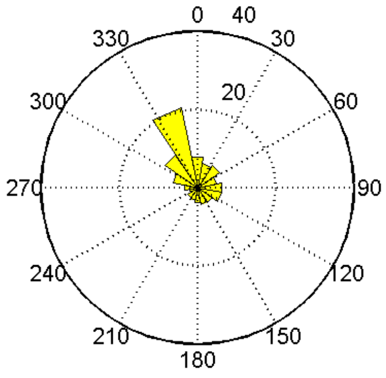
Figure 21: Summary plot of the 30m ADCP's current data at 14.7m.

Koeberg (30m) Period #6
-33.6757N, 18.3898E, at -2.2m depth
4210 good observations
06-Dec-2008 08:38:40 - 07-Jan-2009 13:59:49

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	0.95	1.19	1.62	1.95	2.23	1.97	1.59	1.90	1.62	0.93	1.35	1.16	1.54	1.69	1.24	1.21	24.13
0.1-0.2	2.42	1.81	2.21	1.97	2.80	2.90	2.16	1.83	1.59	1.33	1.00	0.76	1.69	3.56	3.85	3.35	35.23
0.2-0.3	2.95	1.50	1.33	0.57	0.78	1.21	0.64	0.57	0.69	0.59	0.50	0.14	0.19	1.09	2.80	6.96	22.52
0.3-0.4	1.00	0.90	0.64	0.33	0.38	0.19	0.05	0.05	0.05	0.38	0.24			0.02	1.81	5.08	11.12
0.4-0.5	0.69	0.45	0.36	0.05	0.05					0.02					0.21	3.09	4.92
0.5-0.6	0.02	0.19	0.31												0.02	0.97	1.52
0.6-0.7		0.14	0.19												0.02	0.14	0.50
0.7-0.8		0.02															0.02
0.8-0.9		0.05															0.05
0.9-1																	0.00
Σ	8.03	6.25	6.65	4.87	6.25	6.27	4.44	4.35	3.94	3.25	3.09	2.07	3.42	6.37	9.95	20.81	100.00

CURRENT DIRECTION ROSE



CURRENT SPEED HISTOGRAM

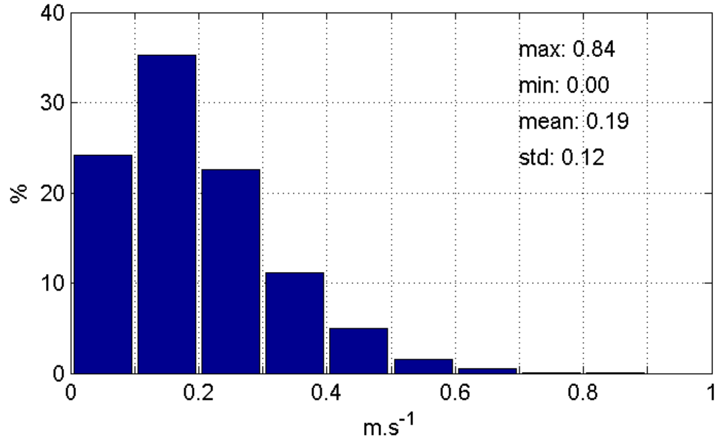


Figure 22: Summary plot of the 30m ADCP’s current data at 2.2m.

5.2.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

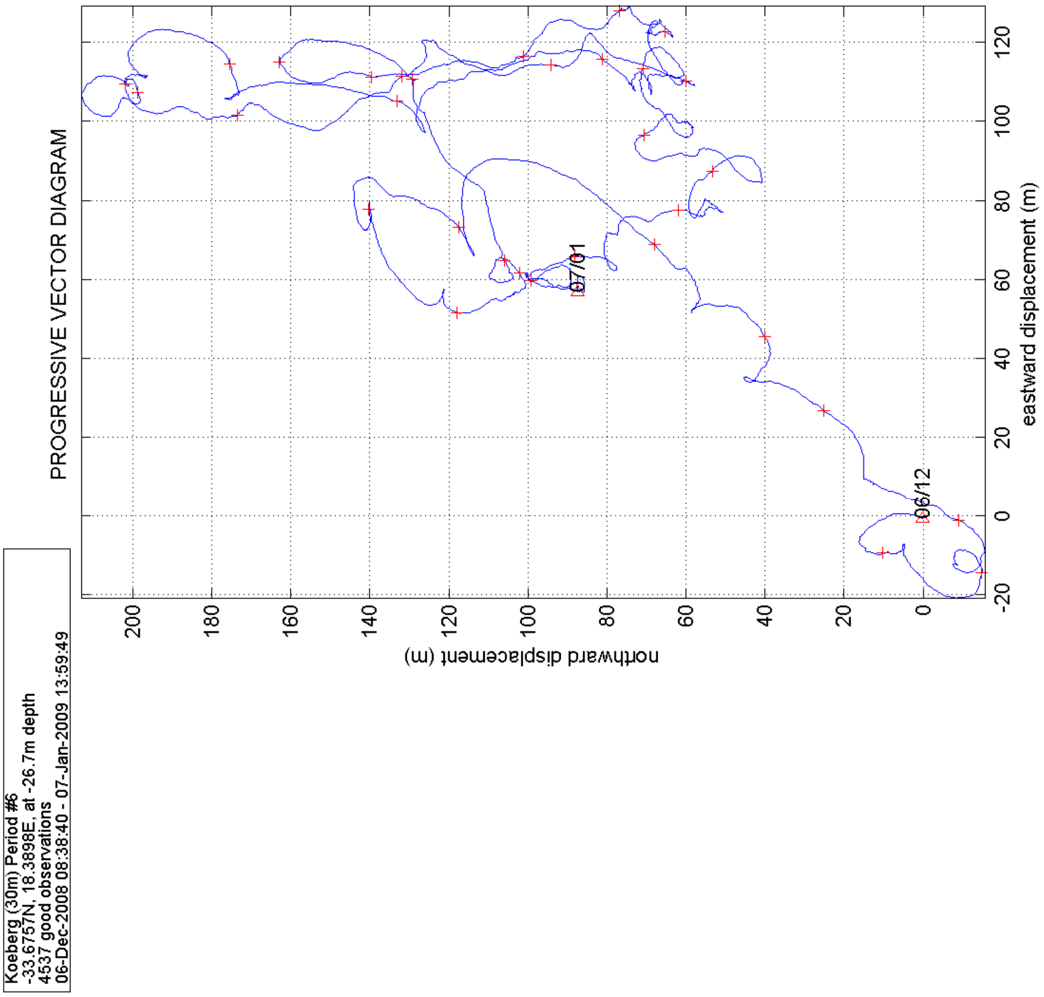


Figure 23: Progressive vector plot of current data at 26.7m.

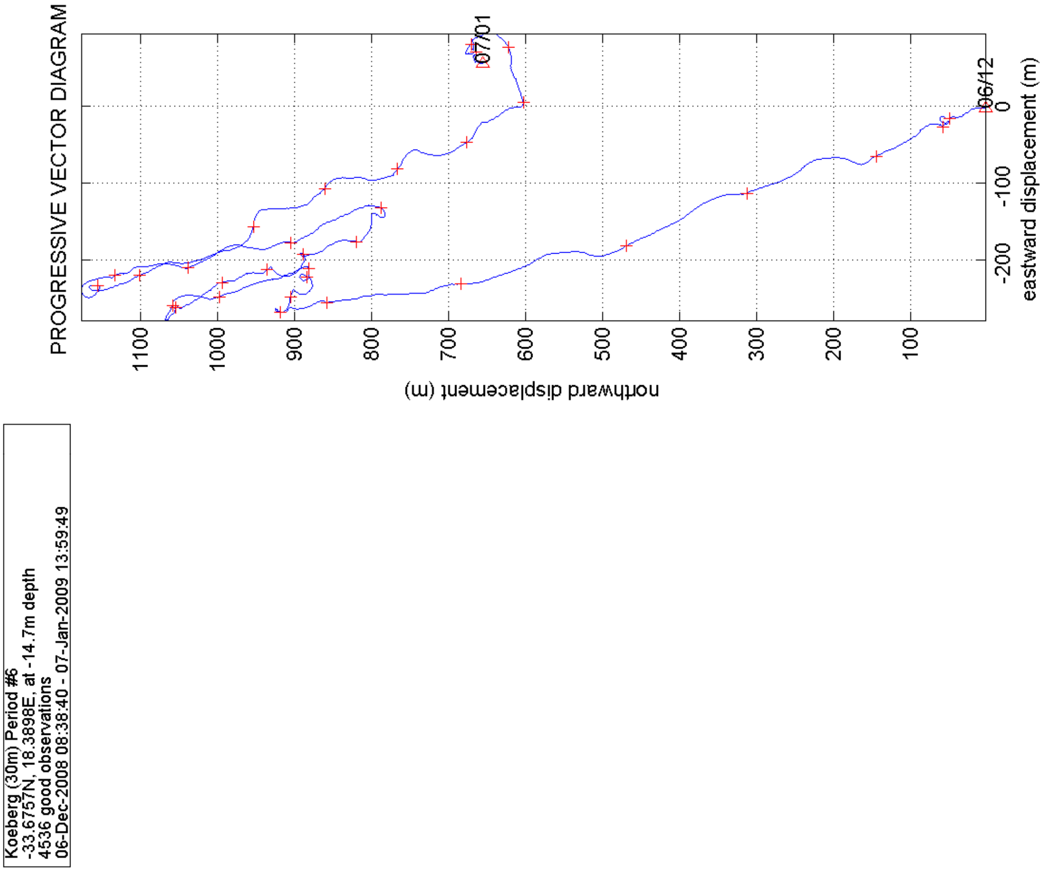


Figure 24: Progressive vector plot of current data at 14.7m.

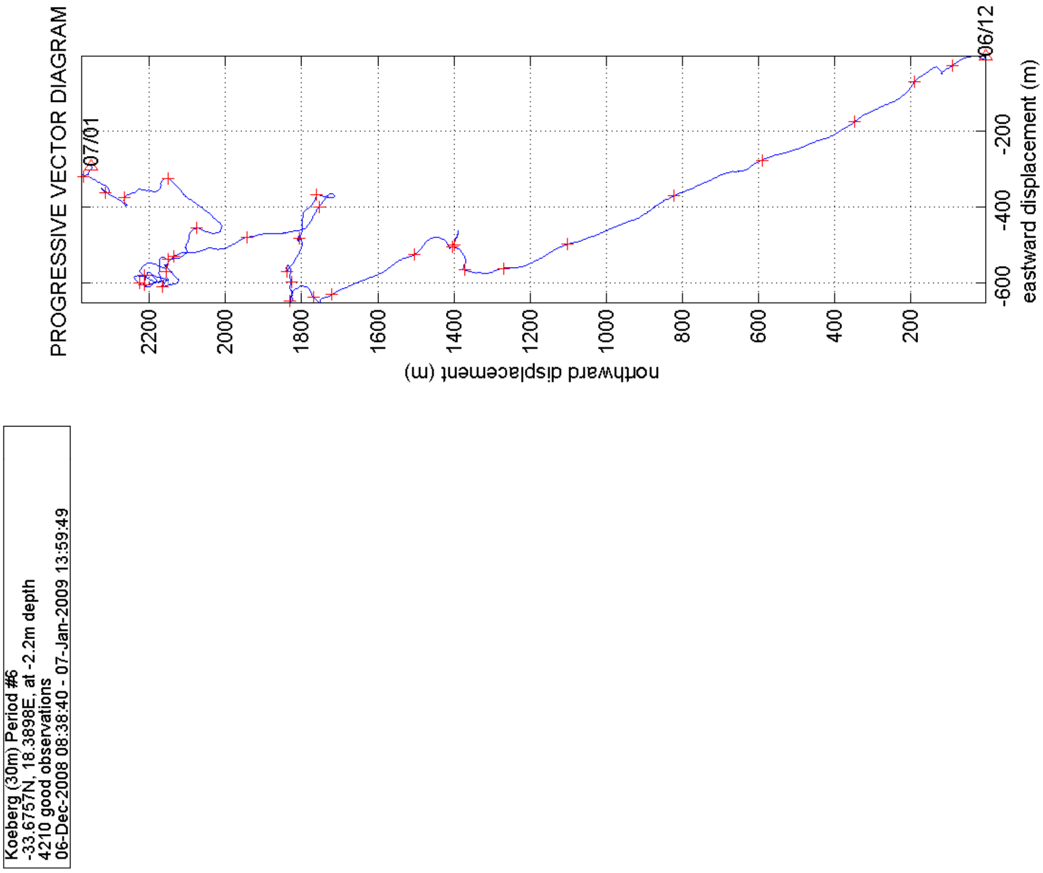


Figure 25: Progressive vector plot of current data at 2.2m.

5.2.2 Wave Data.

5.2.2.1 Hs and Tp summary plot

Figure 26 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.2.2.2 Hs and Dp summary plot

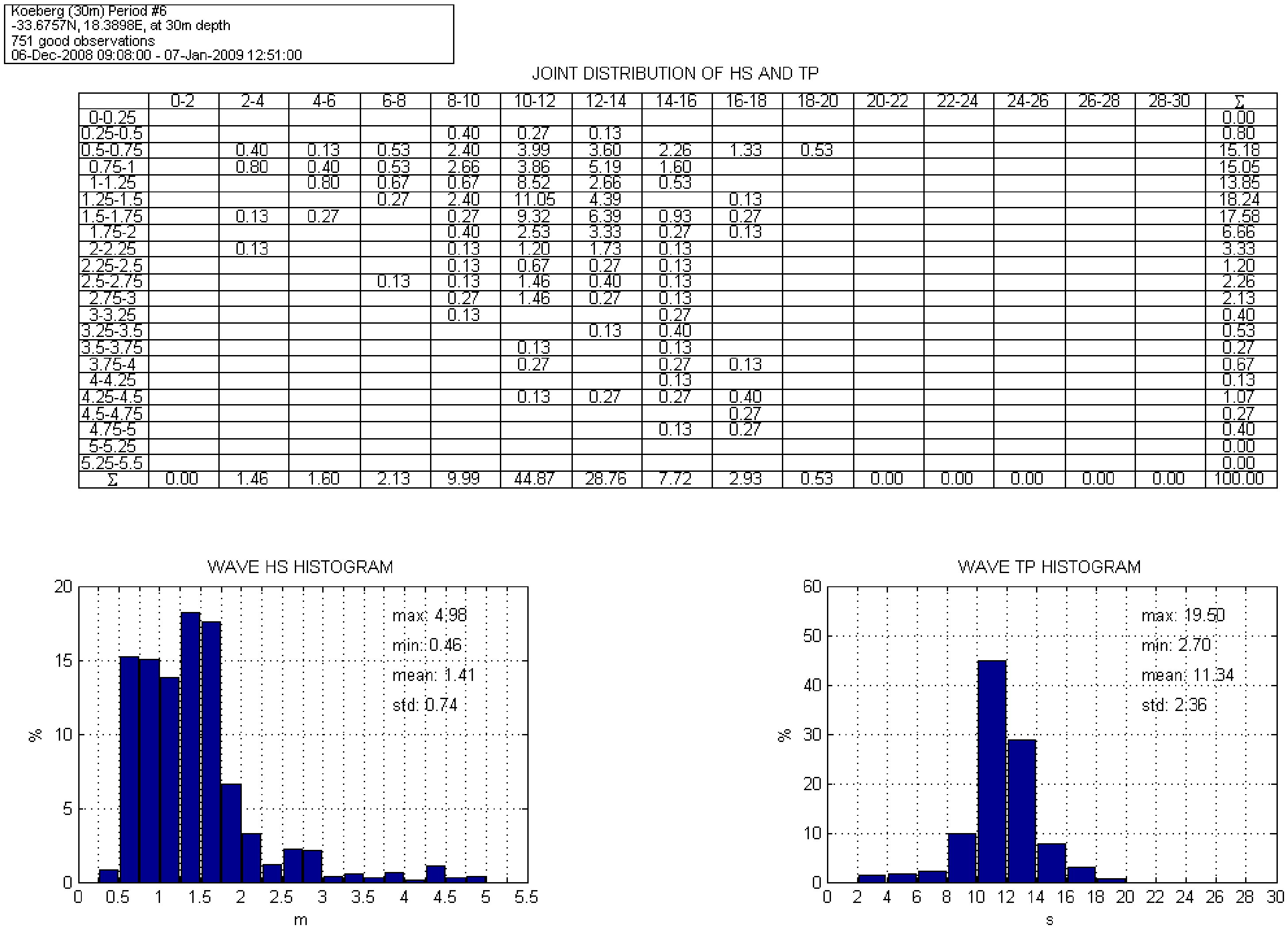
Figure 27 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.2.2.3 Tp and Dp summary plot

Figure 28 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.



Koeberg (30m) Period #6
-33.6757N, 18.3898E, at 30m depth
751 good observations
06-Dec-2008 09:08:00 - 07-Jan-2009 12:51:00

JOINT DISTRIBUTION OF HS AND TP

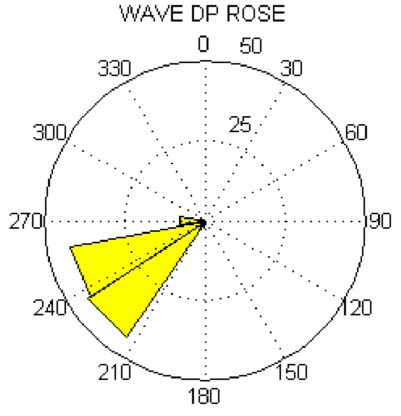
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5					0.40	0.27	0.13									0.80
0.5-0.75		0.40	0.13	0.53	2.40	3.99	3.60	2.26	1.33	0.53						15.18
0.75-1		0.80	0.40	0.53	2.66	3.86	5.19	1.60								15.05
1-1.25			0.80	0.67	0.67	8.52	2.66	0.53								13.85
1.25-1.5				0.27	2.40	11.05	4.39		0.13							18.24
1.5-1.75		0.13	0.27		0.27	9.32	6.39	0.93	0.27							17.58
1.75-2					0.40	2.53	3.33	0.27	0.13							6.66
2-2.25		0.13			0.13	1.20	1.73	0.13								3.33
2.25-2.5					0.13	0.67	0.27	0.13								1.20
2.5-2.75				0.13	0.13	1.46	0.40	0.13								2.26
2.75-3					0.27	1.46	0.27	0.13								2.13
3-3.25					0.13			0.27								0.40
3.25-3.5							0.13	0.40								0.53
3.5-3.75						0.13		0.13								0.27
3.75-4						0.27		0.27	0.13							0.67
4-4.25								0.13								0.13
4.25-4.5						0.13	0.27	0.27	0.40							1.07
4.5-4.75									0.27							0.27
4.75-5								0.13	0.27							0.40
5-5.25																0.00
5.25-5.5																0.00
Σ	0.00	1.46	1.60	2.13	9.99	44.87	28.76	7.72	2.93	0.53	0.00	0.00	0.00	0.00	0.00	100.00

Figure 26: Summary plot of H_s and T_p.

Koeberg (30m) Period #6
-33.6757N, 18.3898E, at 30m depth
751 good observations
06-Dec-2008 09:08:00 - 07-Jan-2009 12:51:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5										0.13	0.40	0.13	0.13				0.80
0.5-0.75										0.53	3.60	4.66	5.06	1.33			15.18
0.75-1								0.13	0.27	0.93	6.39	6.26	0.93		0.13		15.05
1-1.25									0.27	0.40	5.99	6.26	0.53	0.40			13.85
1.25-1.5											7.99	9.85	0.40				18.24
1.5-1.75									0.13	0.27	7.46	9.32	0.40				17.58
1.75-2										0.13	3.06	3.33	0.13				6.66
2-2.25											1.86	1.33	0.13				3.33
2.25-2.5											0.67	0.53					1.20
2.5-2.75											1.60	0.67					2.26
2.75-3											1.86	0.27					2.13
3-3.25											0.40						0.40
3.25-3.5											0.40	0.13					0.53
3.5-3.75											0.13	0.13					0.27
3.75-4											0.67						0.67
4-4.25											0.13						0.13
4.25-4.5											1.07						1.07
4.5-4.75											0.13	0.13					0.27
4.75-5											0.40						0.40
5-5.25																	0.00
5.25-5.5																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.67	2.40	44.21	43.01	7.72	1.73	0.13	0.00	100.00



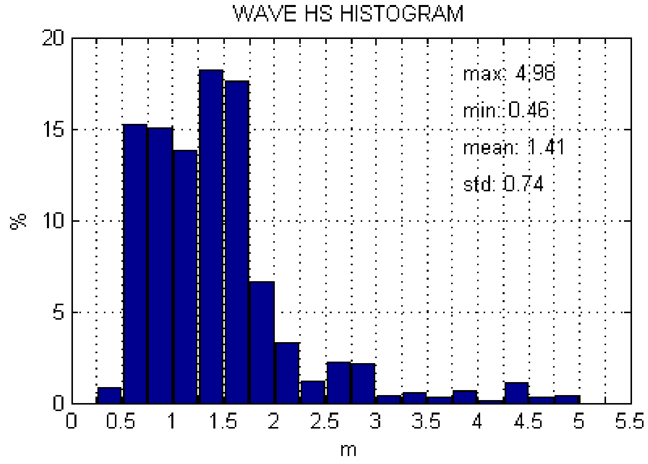


Figure 27: Summary plot of H_s and D_p.

Koeberg (30m) Period #6
-33.6757N, 18.3898E, at 30m depth
751 good observations
06-Dec-2008 09:08:00 - 07-Jan-2009 12:51:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4								0.13	0.27	0.40	0.13	0.13	0.40				1.46
4-6									0.27	0.40	0.40		0.27	0.13	0.13		1.60
6-8									0.13	0.13	1.46	0.13	0.13	0.13			2.13
8-10										0.80	5.99	2.93	0.27				9.99
10-12										0.40	19.97	23.04	1.20	0.27			44.87
12-14										0.27	11.45	14.11	2.80	0.13			28.76
14-16											3.46	2.40	1.33	0.53			7.72
16-18											1.33	0.27	0.93	0.40			2.93
18-20													0.40	0.13			0.53
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.67	2.40	44.21	43.01	7.72	1.73	0.13	0.00	100.00

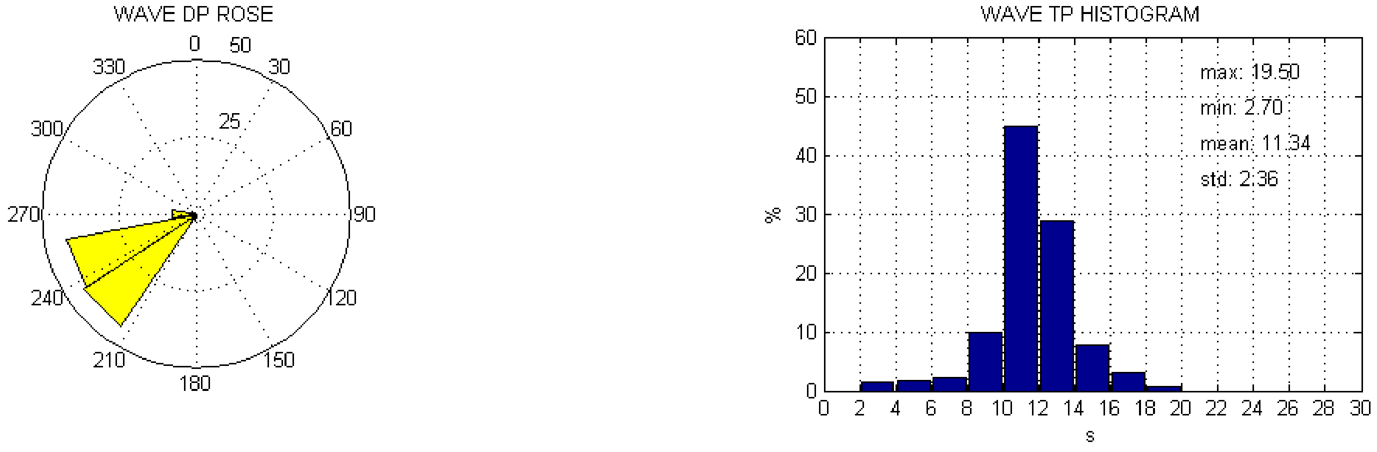


Figure 28: Summary plot of T_p and D_p.

5.2.2.4 Wave spectral plot

Figure 29 displays wave spectral plots for a significant wave event. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

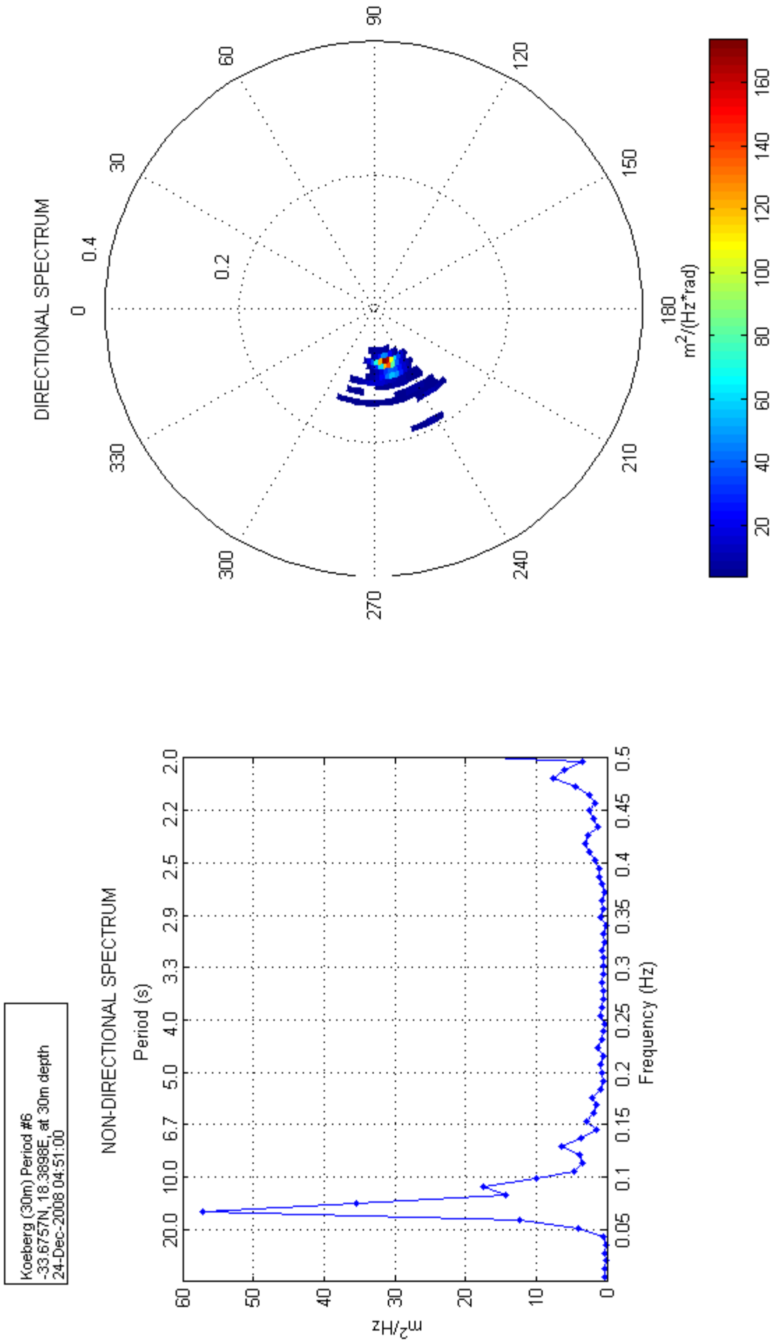


Figure 29: Wave spectra for 24th of December 2008 at 04:51:00.

5.3 COMPARISON PLOTS

5.3.1 Hs, Tp and Dp time series plots for 10m and 30m ADCPs.

Figure 30 displays a time series plot of the main wave parameters:

- The first (upper) panel is of the significant wave height (Hs).
- The second panel is of the peak period (Tp).
- The third panel is of the peak wave direction (Dp).

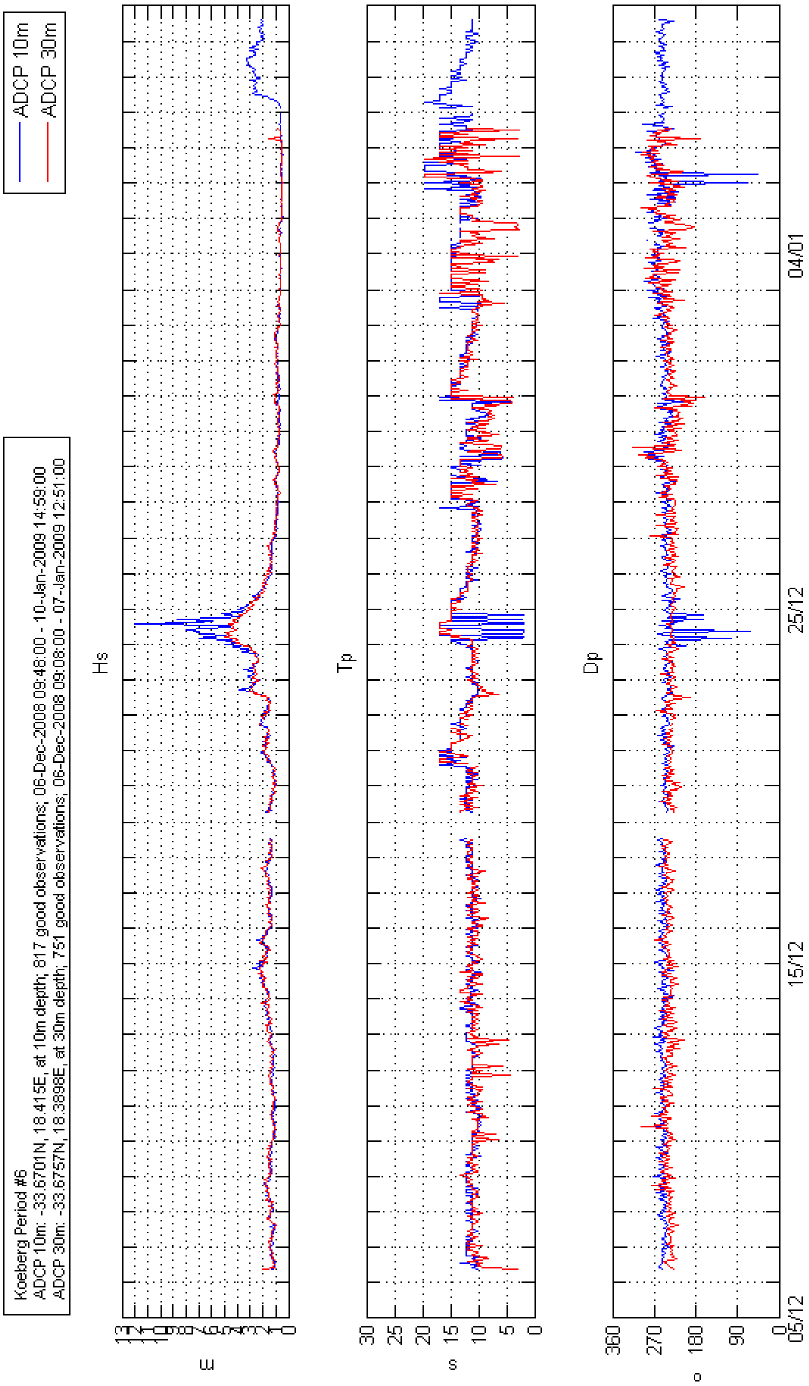


Figure 30: Wave Hs, Tp, and Dp for 10m and 30m ADCP.

5.3.2 Water properties: RBR-CT loggers, Thermister String and ADCPs temperature sensors.

Figure 31 displays a time series plot, which consists of:

- The first panel is of the observed water temperature from surface and bottom RBR loggers, as well as ADCP temperature sensor against time.
- The second panel is of the derived salinity from the two RBR loggers against time.

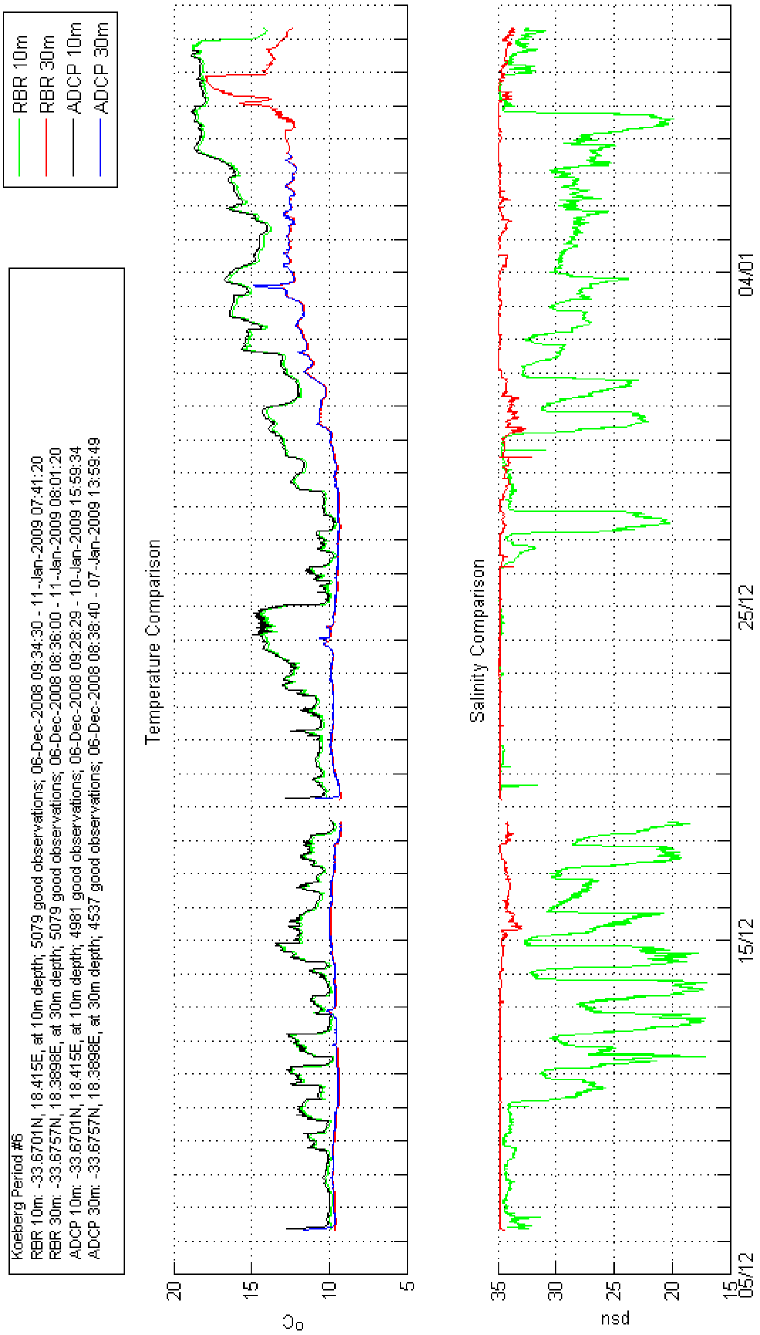


Figure 31: Time series of temperature and salinity from the RBR logger and ADCPs.

6. DISCUSSION

The sixth set of oceanographic data collected at Koeberg for the period between December 6th 2008 and January 11th 2009 has been presented in this report. The measurements taken fall within a larger dataset being compiled to assist a preliminary safety survey of multiple sites around the South African coast reports for Eskom.

At the Koeberg site, 2 600 kHz ADCPs and 2 RBR-CT loggers have been deployed to measure currents, waves and water temperature and salinity. The ADCPs are fixed on a frame at ~10m and ~30m. The RBR loggers are attached to the frame.

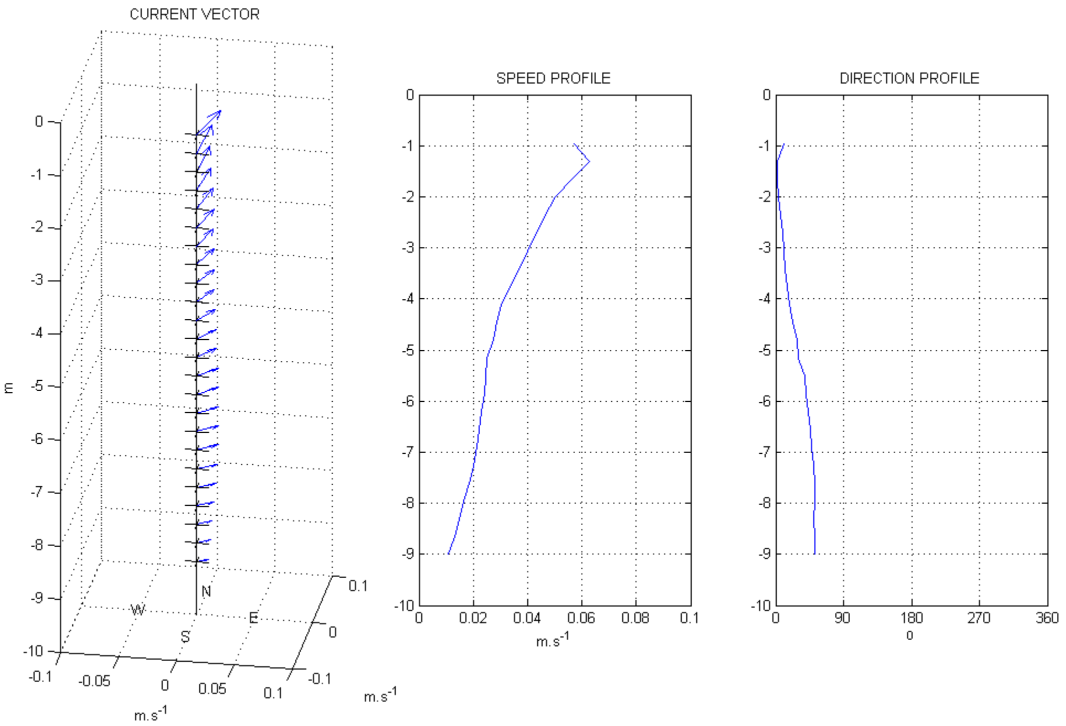


Figure 32: Mean profile plot for 10m ADCP.

The average surface current speed at the 10m site was ~0.18ms^{-1}, decreasing to ~0.09ms^{-1} at ~9m depth. The flow throughout the water column was variable. The mean current profile plot, presented in Figure 32, shows the gradual decrease in the vector mean speed.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.51m, with a wave period of 12.15s and mean direction to W/WSW.

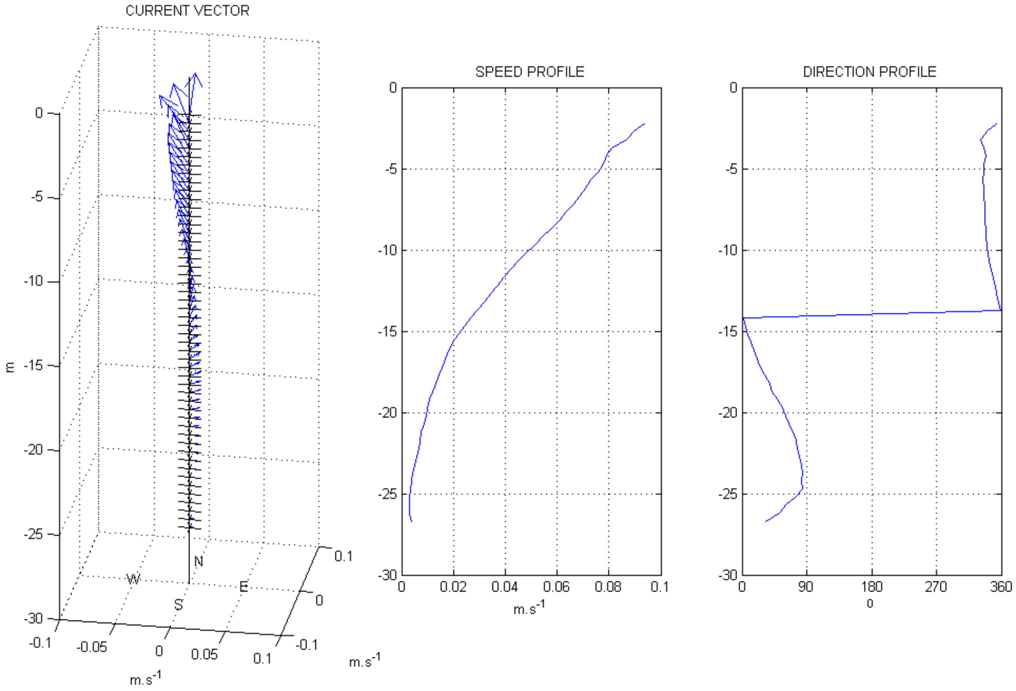


Figure 33: Mean profile plot for 30m ADCP.

The average current speed at the 30m site was ~0.19ms^{-1} at ~2m depth, decreasing to ~0.05ms^{-1} at ~27m depth. The flow throughout the water column was variable.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.41m, with a wave period of 11.34s and mean direction to WSW/SW.

The temperature values recorded from the various independent instruments are in agreement with each other. However, salinity values from the RBR loggers are not consistent. Salinity values at the 10m Site drift possibly due to biofouling around the sensor.

7. INSTRUMENT PARTICULARS FOR SERVICE VISIT SIX

7.1 ADCP RECOVERY AND RE-DEPLOYMENT SHEETS

10m ADCP.

1. RECOVERY **Site Name: Koeberg 10m** **Date: 18 Dec 2008**

Instrument type and serial number			RDI	10841
Recovery date and time	LTx	GMT	**18 Dec 2008 13:57**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LTx	GMT	18 Dec 2008 19:26	
File size			120MB	
Was the data copied to memory card?			Y*	N

2. **RE-DEPLOYMENT** **Site Name: Koeberg 10m** **Date : 19 Dec 2008**

Instrument type and serial number (do not ignore – if same, please indicate)			RDI	**10841**
Install a new battery and/or check the voltage				**1*44.9V**
Frequency of unit being used			**600KHz**	
Depth range			**10m**	
Number of bins (calculated automatically)			**42**	
Bin Size (calculated automatically)			**0.35**	
Wave burst duration			**41min**	
Time between wave bursts			**60min**	
Pings per ensemble			**500**	
Ensemble interval			**10min**	
Deployment duration			**15 days**	
Transducer depth			**10m**	
Any other commands			**RI0,minTP**	
Temperature			**5**	
Recorder size			**2 * 1GB**	

Consequences of the sampling parameters

First and last bin range			**1.41**	**15.76**
Battery usage				**440Wh**
Standard deviation				**1.08**
Storage space required				**113MB**
Set the ADCP clock	LT-x	GMT	**18 Dec 2008 21:57:42**	
Run pre-deployment tests				**Yes**
Name the ADCP deployment			**K1013**	

Deployment details

Switch on date and time	LTx	GMT	**18 Dec 2008 21:58**
Deployment date and time	LTx	GMT	**19 Dec 2008 06:55**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.206**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.897**

Site depth	10m	Deployment depth	**10m**
Acoustic release (1) serial number and release code			
Acoustic release (2) serial number and release code			
Argos beacon serial number		**-**	
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)		**K1013**	

3. RECOVERY Site Name: Koeberg 10m Date: 11 Jan 2009

Instrument type and serial number		RDI	10841
Recovery date and time	LTx	GMT	11 jan 2009 08:44
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**
Switch off date and time	LTx	GMT	11 Jan 2009 11:54
File size			218MB
Was the data copied to memory card?		Y*	N

4. RE-DEPLOYMENT Site Name: Koeberg 10m Date : 15 Jan 2009

Instrument type and serial number (do not ignore – if same, please indicate)		RDI	**10841**
Install a new battery and/or check the voltage			**1*44.9V**
Frequency of unit being used			**600KHz**
Depth range			**10m**
Number of bins (calculated automatically)			**42**
Bin Size (calculated automatically)			**0.35**
Wave burst duration			**41min**
Time between wave bursts			**60min**
Pings per ensemble			**500**
Ensemble interval			**10min**
Deployment duration			**15 days**
Transducer depth			**10m**
Any other commands			**RI0,minTP**
Temperature			**5**
Recorder size			**2 * 1GB**

Consequences of the sampling parameters

First and last bin range		**1.41**	**15.76**
Battery usage			**440Wh**
Standard deviation			**1.08**
Storage space required			**113MB**
Set the ADCP clock	LT-x	GMT	**15 Jan 2009 09:42:00**
Run pre-deployment tests			**Yes**
Name the ADCP deployment			**K1001**

Deployment details

Switch on date and time	LTx	GMT	**15 Jan 2009 11:30:00**
Deployment date and time	LTx	GMT	**15 Jan 2009 14:25:00**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.206**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.897**

Site depth	10m	Deployment depth		**10m**
Acoustic release (1) serial number and release code				
Acoustic release (2) serial number and release code				
Argos beacon serial number			**-**	
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**K1001**	

30m ADCP.

1. RECOVERY Site Name: Koeberg 30m Date: 18 Dec 2008 .

Instrument type and serial number			RDI	10119
Recovery date and time	LTx	GMT	**12h53 18 Dec 2008**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**	
Switch off date and time	LTx	GMT	07h25 18 Dec 2008	
File size			104MB	
Was the data copied to memory card?			Yx	N

2. **RE-DEPLOYMENT Site Name: Koeberg 30m Date: 19 Dec 2008 .**

Instrument type and serial number (do not ignore – if same, please indicate)			RDI	**10119**
Install a new battery and/or check the voltage				**1*44.9V**
Frequency of unit being used			**600KHz**	
Depth range			**30m**	
Number of bins (calculated automatically)			**69**	
Bin Size (calculated automatically)			**0.5**	
Wave burst duration			**34.16min**	
Time between wave bursts			**60min**	
Pings per ensemble			**250**	
Ensemble interval			**10min**	
Deployment duration			**15 days**	
Transducer depth			**30m**	
Any other commands			**RI0,minTP**	
Temperature			**5**	
Recorder size	**1128MB**			

Consequences of the sampling parameters

First and last bin range			**1.6**	**35.6**
Battery usage				**449Wh**
Standard deviation				**0. 86**
Storage space required				**112MB**
Set the ADCP clock	LT-x	GMT	**18 Dec 2008 21:51:00**	
Run pre-deployment tests				**Yes**
Name the ADCP deployment	**K3013**			

Deployment details

Switch on date and time	LT-x	GMT	**18 Dec 2008 09:51:00**
Deployment date and time	LT-x	GMT	**19 Dec 2008 06:00**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**

Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Site depth	30m	Deployment depth	**30m**
Acoustic release (1) serial number and release code			**32385**
Acoustic release (2) serial number and release code			
Argos beacon serial number			
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**K3013**

3. RECOVERY Site Name: Koeberg 30m Date: 11 Jan 2009

Instrument type and serial number		RDI	10119
Recovery date and time	LTx	GMT	11 Jan 2009 08:15
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Switch off date and time	LTx	GMT	11 Jan 2009 11:52
File size			158MB
Was the data copied to memory card?		Yx	N

4. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 15 Jan 2009 .

Instrument type and serial number (do not ignore – if same, please indicate)	RDI	**10119**
Install a new battery and/or check the voltage		**1*44.9V**
Frequency of unit being used	**600KHz**	
Depth range	**30m**	
Number of bins (calculated automatically)	**69**	
Bin Size (calculated automatically)	**0.5**	
Wave burst duration	**34.16min**	
Time between wave bursts	**60min**	
Pings per ensemble	**250**	
Ensemble interval	**10min**	
Deployment duration	**15 days**	
Transducer depth	**30m**	
Any other commands	**RI0,minTP**	
Temperature	**5**	
Recorder size	**1128MB**	

Consequences of the sampling parameters

First and last bin range		**1.6**	**35.6**
Battery usage			**449Wh**
Standard deviation			**0. 86**
Storage space required			**112MB**
Set the ADCP clock	LT-x	GMT	**11 Jan 2009 09:52:00**
Run pre-deployment tests			**Yes**
Name the ADCP deployment			**K3001**

Deployment details

Switch on date and time	LT-x	GMT	**11 Jan 2009 11:30:00**
Deployment date and time	LT-x	GMT	**15 Jan 2009 13:40:00**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**

Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Site depth	30m	Deployment depth	**30m**
Acoustic release (1) serial number and release code			**32385**
Acoustic release (2) serial number and release code			
Argos beacon serial number			
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**K3001**

7.2 RBR-CT LOGGERS RECOVERY AND RE-DEPLOYMENT SHEETS

10m Logger.

1. RECOVERY Site Name: Koeberg 10m Date: 18 Dec 2008

Instrument type and serial number			XR 420	12995
Recovery date and time	LTx	GMT	**18 Dec 2008 13:57**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LT	GMT	18 Dec 2008 22:24:38	
File size			42KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 18 December 2008/RBR_RecoveredData	

2. RE-DEPLOYMENT Site Name: Koeberg 10m Date: 19 Dec 2008

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12995
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	18 Dec 2008	22:30:10
End of logging (date / time)	27 Jan 2009	12h00
Memory usage		.4%
Battery usage		986mAH

Deployment details

Deployment date and time	LT	GMT	19 Dec 2008 06h55	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Site name			Koeberg 10m	
Site depth			10m	
Deployment depth			10m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 18 December 2008/RBR_RecoveredData/**012995**	

5. RECOVERY Site Name: Koeberg 10m Date: 11 Jan 2009

Instrument type and serial number			XR 420	12995
Recovery date and time	LTx	GMT	**11 Jan 2009 08:44**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LT	GMT	11 Jan 2009 12:02	
File size			74KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 11 January 2009/RBR_RecoveredData	

6. RE-DEPLOYMENT Site Name: Koeberg 10m Date: 15 Jan 2009

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12995
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	15 Jan 2009	11:30:00
End of logging (date / time)	24 Feb 2009	12h00
Memory usage		.4%
Battery usage		997mAH

Deployment details

Deployment date and time	LT	GMT	15 Jan 2009 13:40:00	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Site name			Koeberg 10m	
Site depth			10m	
Deployment depth			10m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 11 Jan 2009/RBR_RecoveredData/**012995**	

30m Logger.

1. RECOVERY Site Name: Koeberg 30m Date: 18 Dec 2008.

Instrument type and serial number			XR 420	12997
Recovery date and time	LT	GMT	**18 Dec 2008 12:53**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**	
Switch off date and time	LT	GMT	18 Dec 2008 22:22:25	
File size			42KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 18 December 2008/RBR_RecoveredData	

2. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 19 Dec 2008

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12997
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	18 Dec 2008	22:30:10
End of logging (date / time)	27 Jan 2009	12h00
Memory usage		.4%
Battery usage		986mAH

Deployment details

Deployment date and time	LT - x	GMT	19 Dec 2008 06h00	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**	
Site name			Koeberg 30m	
Site depth			30m	
Deployment depth			30m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 18 December 2008/RBR_RecoveredData/**012997.log**	

3. RECOVERY Site Name: Koeberg 30m Date: 11 Jan 2009

Instrument type and serial number			XR 420	12997
Recovery date and time	LT	GMT	**11 Jan 2009 08:15**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	

Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Switch off date and time	LT	GMT	11 Jan 2009 11:58
File size			74KB
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 11 January 2009/RBR_RecoveredData

4. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 15 Jan 2009

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12997
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period		**10 min**
Averaging period		**1 min**
Expected deployment duration		**3 weeks**
Start of logging (date / time)	15 Jan 2009	11:30:00
End of logging (date / time)	24 Feb 2009	12h00
Memory usage		.4%
Battery usage		997mAH

Deployment details

Deployment date and time	LT - x	GMT	15 Jan 2009 14:25:00
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.397**
Site name			Koeberg 30m
Site depth			30m
Deployment depth			30m
Acoustic release (1) serial number and release code			**-**
Acoustic release (2) serial number and release code			**-**
Argos beacon serial number			**-**
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 15 Jan 2009/RBR_RecoveredData/**012997.log**

7.3 ADCP CONFIGURATION FILES

10m ADCP.

```
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 360.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 2000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 133.83 MB (140329440 bytes)
;Power usage         = 440.26 Wh
;Battery usage       = 1.0
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
```

```
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.


CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4920
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
TF09/01/15 11:30:00
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 360.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1256
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 133.83 MB (140329440 bytes)
;Power usage         = 440.26 Wh
```

```
;Battery usage      = 1.0
;Samples / Wv Burst = 4920
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 383840
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

30m ADCP.

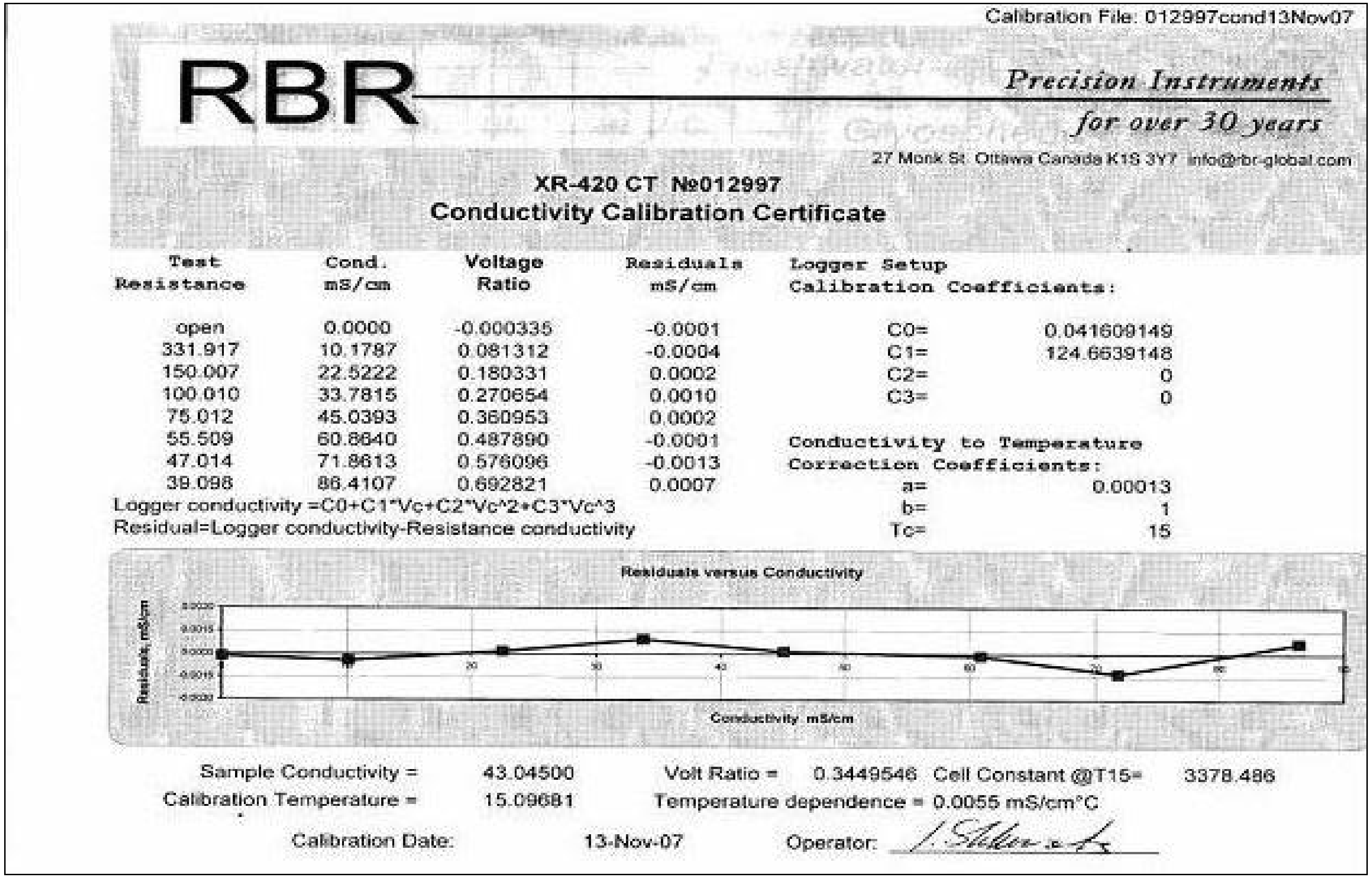
```
CR1
CF11101
EA0
EB0
ED300
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN69
WP250
WS50
WV175
HD111000000
HB5
HP4080
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 360.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 2000
```

```
;Saved Screen       = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range   = 1.60 m
;Last cell range    = 35.60 m
;Max range          = 38.22 m
;Standard deviation = 0.86 cm/s
;Ensemble size      = 1534 bytes
;Storage required   = 112.45 MB (117908640 bytes)
;Power usage        = 447.68 Wh
;Battery usage      = 1.0
;Samples / Wv Burst = 4080
;Min NonDir Wave Per= 2.59 s
;Min Dir Wave Period= 4.31 s
;Bytes / Wave Burst = 318320
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.


CR1
CF11101
EA0
EB0
ED300
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN69
WP250
WS50
WV175
HD111000000
HB5
HP4080
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
TF09/01/15 11:30:00
CK
CS
;
;Instrument         = Workhorse Sentinel
;Frequency          = 614400
;Water Profile      = YES
;Bottom Track       = NO
;High Res. Modes    = NO
;High Rate Pinging  = NO
;Shallow Bottom Mode= NO
;Wave Gauge         = YES
;Lowered ADCP       = NO
;Beam angle         = 20
```

```
;Temperature          = 5.00
;Deployment hours     = 360.00
;Battery packs        = 1
;Automatic TP         = NO
;Memory size [MB]     = 1256
;Saved Screen         = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range     = 1.60 m
;Last cell range      = 35.60 m
;Max range            = 38.22 m
;Standard deviation = 0.86 cm/s
;Ensemble size        = 1534 bytes
;Storage required     = 112.45 MB (117908640 bytes)
;Power usage          = 447.68 Wh
;Battery usage        = 1.0
;Samples / Wv Burst = 4080
;Min NonDir Wave Per= 2.59 s
;Min Dir Wave Period= 4.31 s
;Bytes / Wave Burst = 318320
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

7.4 RBR-CT CALIBRATION CERTIFICATES



Calibration File: 012997cond13Nov07

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012997
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000335	-0.0001
331.917	10.1787	0.081312	-0.0004
150.007	22.5222	0.180331	0.0002
100.010	33.7815	0.270654	0.0010
75.012	45.0393	0.360953	0.0002
55.509	60.8640	0.487890	-0.0001
47.014	71.8613	0.576096	-0.0013
39.098	86.4107	0.692821	0.0007

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

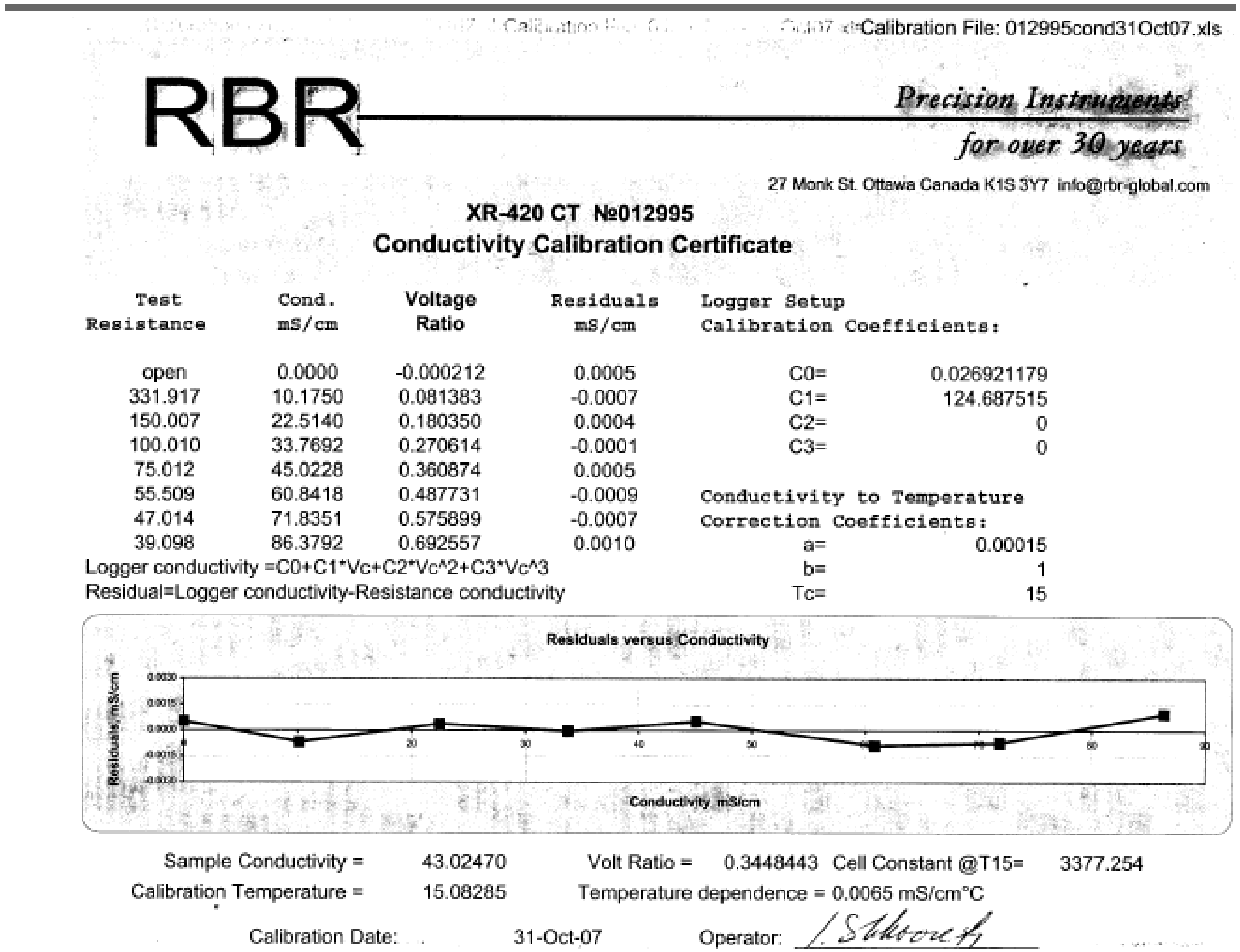
Logger Setup
Calibration Coefficients:

C0= 0.041609149
C1= 124.6639148
C2= 0
C3= 0

Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Sample Conductivity = 43.04500
Calibration Temperature = 15.09681
Volt Ratio = 0.3449546
Cell Constant @T15= 3378.486
Temperature dependence = 0.0055 mS/cm°C
Calibration Date: 13-Nov-07
Operator: J. Sh



Calibration File: 012995cond31Oct07.xls

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012995
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000212	0.0005
331.917	10.1750	0.081383	-0.0007
150.007	22.5140	0.180350	0.0004
100.010	33.7692	0.270614	-0.0001
75.012	45.0228	0.360874	0.0005
55.509	60.8418	0.487731	-0.0009
47.014	71.8351	0.575899	-0.0007
39.098	86.3792	0.692557	0.0010

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.026921179
C1= 124.687515
C2= 0
C3= 0

Conductivity to Temperature
Correction Coefficients:

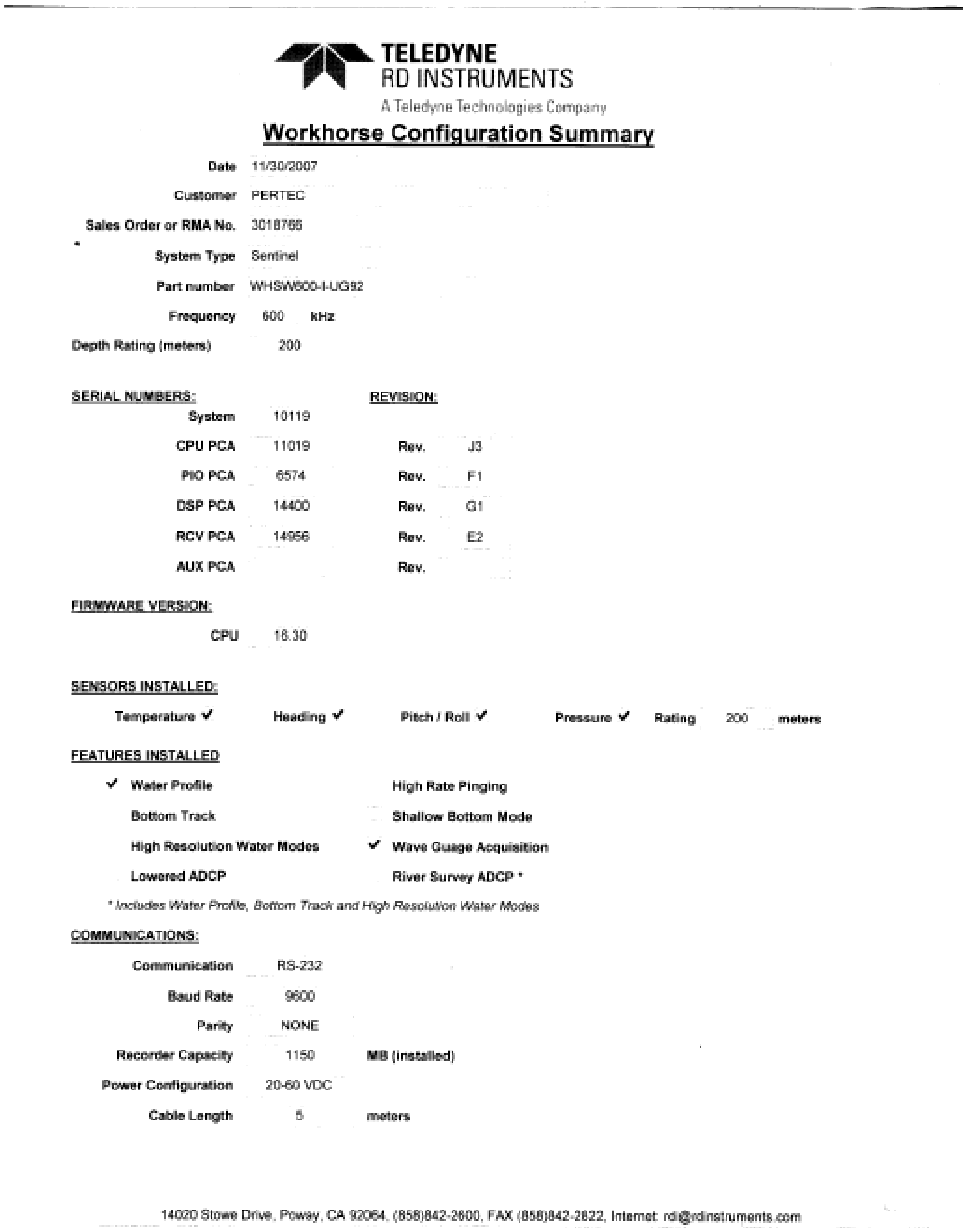
a= 0.00015
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 43.02470 Volt Ratio = 0.3448443 Cell Constant @T15= 3377.254
Calibration Temperature = 15.08285 Temperature dependence = 0.0065 mS/cm°C

Calibration Date: 31-Oct-07 Operator: I. Shkvorets

7.5 TRDI ADCP CALIBRATION CERTIFICATE



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 11/30/2007

Customer PERTEC

Sales Order or RMA No. 3018766

System Type Sentinel

Part number WHSW600-I-UG92

Frequency 600 **kHz**

Depth Rating (meters) 200

SERIAL NUMBERS: **REVISION:**

System	10119		
CPU PCA	11019	**Rev.**	J3
PIO PCA	6574	**Rev.**	F1
DSP PCA	14400	**Rev.**	G1
RCV PCA	14956	**Rev.**	E2
AUX PCA		**Rev.**	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ **Heading** ✓ **Pitch / Roll** ✓ **Pressure** ✓ **Rating** 200 **meters**

FEATURES INSTALLED

✓ **Water Profile**	**High Rate Pinging**
Bottom Track	**Shallow Bottom Mode**
High Resolution Water Modes	✓ **Wave Guage Acquisition**
Lowered ADCP	**River Survey ADCP ***

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232

Baud Rate 9600

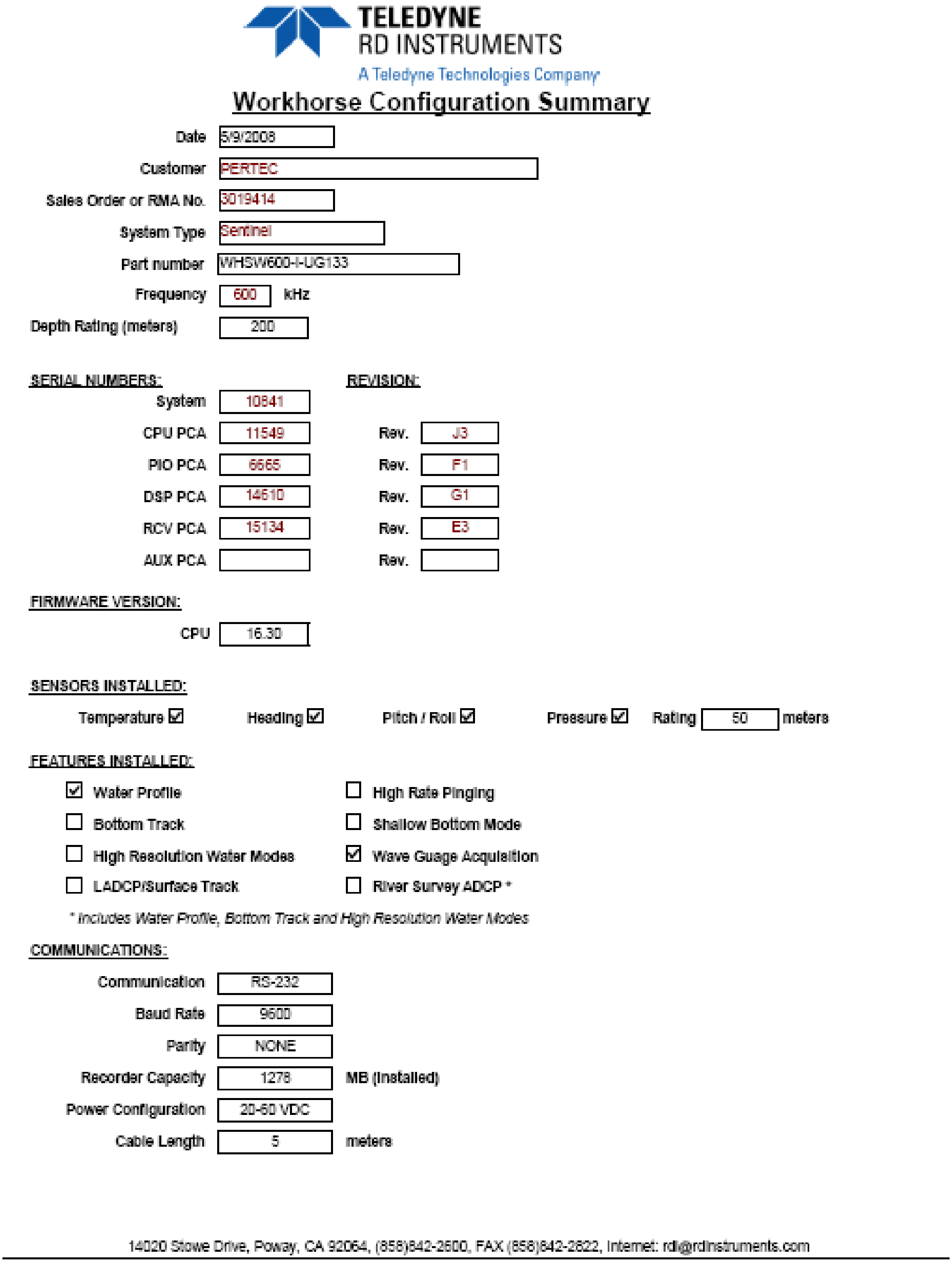
Parity NONE

Recorder Capacity 1150 **MB (installed)**

Power Configuration 20-60 VDC

Cable Length 5 **meters**

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 5/9/2008

Customer PERTEC

Sales Order or RMA No. 3019414

System Type Sentinel

Part number WHSW600-I-UG133

Frequency 600 kHz

Depth Rating (meters) 200

SERIAL NUMBERS: / **REVISION:**

System	10841		
CPU PCA	11549	Rev.	J3
PIO PCA	6665	Rev.	F1
DSP PCA	14610	Rev.	G1
RCV PCA	15134	Rev.	E3
AUX PCA		Rev.	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ☑ Heading ☑ Pitch / Roll ☑ Pressure ☑ Rating 50 meters

FEATURES INSTALLED:

- ☑ Water Profile
- ☐ Bottom Track
- ☐ High Resolution Water Modes
- ☐ LADCP/Surface Track
- ☐ High Rate Pinging
- ☐ Shallow Bottom Mode
- ☑ Wave Guage Acquisition
- ☐ River Survey ADCP *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232

Baud Rate 9600

Parity NONE

Recorder Capacity 1278 MB (Installed)

Power Configuration 20-60 VDC

Cable Length 5 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2622, Internet: rdi@rdinstruments.com

LWANDLE TECHNOLOGIES (PTY) LTD

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT SEVEN

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

12 May 2009

Job No: LT-JOB-50

Directors: C.P. Matthysen, M. Majodina, B.J. Spolander

LWANDLE TECHNOLOGIES (PTY) LTD
Unit 13/15 Constantia Business Park, Princess Vlei Road,
Diep River, 7800, South Africa

Co Reg. No. 2003/015524/07

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 6 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary for 10m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-8.8	100	0.5704	0.1034	0.1088	0.0610	27.52
-8.4	100	0.5949	0.1076	0.1122	0.0665	27.39
-8.1	99.97	0.6051	0.1115	0.1156	0.0706	27.19
-7.7	100	0.5949	0.1161	0.1183	0.0752	26.13
-7.4	100	0.5903	0.1204	0.1207	0.0793	25.08
-7.0	100	0.6095	0.1251	0.1237	0.0840	23.98
-6.7	100	0.5953	0.1295	0.1260	0.0885	22.66
-6.3	100	0.6083	0.1341	0.1283	0.0938	21.57
-6.0	100	0.6116	0.1388	0.1309	0.0990	20.28
-5.6	100	0.6294	0.1422	0.1332	0.1051	19.52
-5.3	100	0.6275	0.1404	0.1307	0.1050	19.73
-4.9	100	0.6298	0.1531	0.1389	0.1149	16.44
-4.6	100	0.6496	0.1586	0.1420	0.1203	14.70
-4.2	100	0.6604	0.1645	0.1440	0.1261	13.66
-3.9	100	0.6804	0.1706	0.1463	0.1320	13.62
-3.5	100	0.6825	0.1777	0.1494	0.1391	13.17
-3.2	100	0.6806	0.1847	0.1518	0.1452	11.95
-2.8	100	0.6953	0.1904	0.1545	0.1509	10.96
-2.5	100	0.7147	0.1977	0.1575	0.1572	10.76
-2.1	100	0.7414	0.2041	0.1590	0.1623	11.08
-1.8	100	0.7405	0.2112	0.1611	0.1683	11.42
-1.4	99.93	0.7434	0.2214	0.1624	0.1755	12.32
-1.1	92.89	0.8497	0.2306	0.1677	0.1821	14.46

Table 2 – Waves summary for 10m ADCP

	Data Return (%)	Max	Min	Mean	Std
Hs (m)	1099.22	4.91	1.49	0.66	0.66
Tp (s)	1099.22	15.00	11.44	6.20	1.74
Dp (^{o})	1099.22	284.72	259.48	234.72	7.28

Table 3 – Current flow summary for 30m ADCP

Depth (m)	Data return (%)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (□)
-26.5	100	0.1843	0.0594	0.0333	0.0127	26.96
-26.0	100	0.1768	0.0634	0.0346	0.0125	28.74
-25.5	100	0.1821	0.0663	0.0353	0.0119	28.83
-25.0	100	0.1953	0.0696	0.0366	0.0119	28.69
-24.5	100	0.1914	0.0722	0.0372	0.0123	27.32
-24.0	100	0.1994	0.0748	0.0382	0.0128	24.63
-23.5	100	0.2416	0.0775	0.0388	0.0135	21.88
-23.0	100	0.2253	0.0802	0.0397	0.0147	18.25
-22.5	100	0.2374	0.0823	0.0401	0.0158	15.76
-22.0	100	0.2438	0.0847	0.0407	0.0179	12.41
-21.5	100	0.2340	0.0868	0.0415	0.0197	9.080
-21.0	100	0.2374	0.0891	0.0423	0.0221	4.54
-20.5	100	0.2450	0.0912	0.0430	0.0249	2.30
-20.0	100	0.2693	0.0935	0.0443	0.0275	0.59
-19.5	100	0.2580	0.0957	0.0453	0.0303	359.31
-19.0	100	0.2578	0.0981	0.0463	0.0337	357.90
-18.5	100	0.2893	0.1007	0.0478	0.0367	358.12
-18.0	100	0.2953	0.1038	0.0493	0.0402	357.13
-17.5	100	0.3168	0.1066	0.0503	0.0433	356.15
-17.0	100	0.3421	0.1095	0.0520	0.0469	355.20
-16.5	100	0.3541	0.1132	0.0534	0.0503	355.21
-16.0	100	0.3738	0.1163	0.0554	0.0534	354.61
-15.5	100	0.3877	0.1199	0.0572	0.0564	354.85
-15.0	100	0.4028	0.1233	0.0596	0.059	354.17
-14.5	100	0.4422	0.1263	0.0615	0.0616	353.94
-14.0	100	0.4557	0.1295	0.0635	0.0639	352.38
-13.5	100	0.4583	0.1329	0.0657	0.0664	350.39
-13.0	100	0.4642	0.1351	0.0679	0.0685	348.35
-12.5	100	0.5087	0.1377	0.0711	0.0709	345.68
-12.0	100	0.5179	0.1409	0.0734	0.0733	342.61
-11.5	100	0.5410	0.1438	0.0768	0.0762	339.51
-11.0	100	0.5660	0.1471	0.0794	0.0791	336.75
-10.5	100	0.5923	0.1507	0.0829	0.0826	333.84
-10.0	100	0.6019	0.1551	0.0866	0.0867	330.93
-9.5	100	0.6172	0.1594	0.0897	0.0915	328.58
-9.0	100	0.6291	0.1639	0.0934	0.0963	326.90
-8.5	100	0.6544	0.1683	0.0973	0.1011	325.99
-8.0	100	0.6693	0.1726	0.1014	0.1062	325.15
-7.5	100	0.6891	0.1764	0.1057	0.1112	324.61

-7.0	100	0.7241	0.1800	0.1101	0.1165	324.31
-6.5	100	0.7404	0.1831	0.1149	0.1217	323.60
-6.0	100	0.7550	0.1861	0.1189	0.1266	323.48
-5.5	99.96	0.7675	0.1895	0.1235	0.1317	323.27
-5.0	99.93	0.7877	0.1929	0.1266	0.1366	323.34
-4.5	99.86	0.8243	0.1969	0.1296	0.1407	323.81
-4.0	99.86	0.8405	0.2012	0.1315	0.1444	324.66
-3.5	99.93	0.8595	0.2042	0.1325	0.1449	327.04
-3.0	99.75	0.8689	0.2068	0.1325	0.1428	333.05
-2.5	99.79	0.8971	0.2127	0.1318	0.1462	342.66
-2.0	80.35	0.8817	0.2157	0.1348	0.1527	348.20

Table 4 – Waves summary for 30m ADCP

	Data Return (%)	**Max**	**Min**	**Mean**	**Std**
Hs (m)	3098.52	3.48	0.66	1.53	0.60
Tp (s)	3098.52	14.90	4.10	10.88	1.78
Dp (^{o})	3098.52	310.72	174.72	229.08	11.30

Table 5 – Water temperature and salinity summary for 10m RBR logger

Parameter	**Data Return (%)**	**Mean**	**Max**	**Min**
Temperature (^{o}C)	100	11.32	15.64	9.49
Conductivity	100	27.32	43.42	10.08
Salinity (psu)	22.97	34.79	34.98	34.00

Table 6 – Water temperature and salinity summary for 30m RBR logger

Parameter	**Data Return (%)**	**Mean**	**Max**	**Min**
Temperature (^{o}C)	100	10.09	11.44	9.15
Conductivity	100	37.59	39.40	34.21
Salinity (psu)	100	34.40	35.02	31.22

1.1 DATA RETURN FOR KOEBERG SITE.

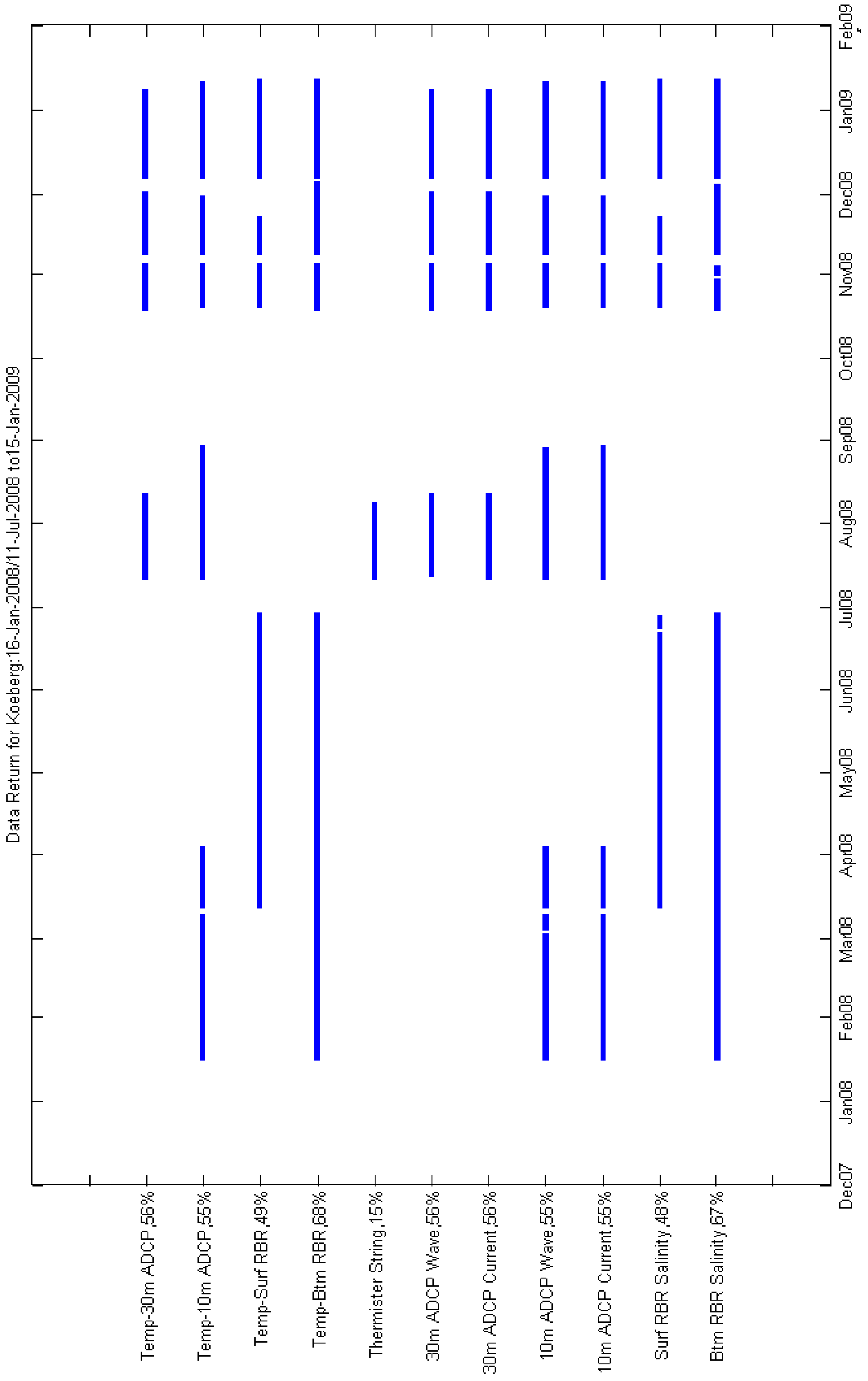


Figure 1: An indication of the data return (%) at the Koeberg site since the beginning of the project (Jan 16th 2008; July 11th 2008 for 30m ADCP and Thermister String). A break down of the temperature (Temp) return from all available instruments is given in the top 5 bars.

2. INTRODUCTION

2.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period December 6th 2008 - January 11th 2009 (Period 6). Service of the instruments was undertaken twice: December 18 – 19th 2008 and January 11 – 15th 2009.

2.2 EQUIPMENT LIST

Lwandle provided the equipment as listed in Table 7 for the Koeberg site.

Table 7 – List of equipment provided.

Item	Operational (on site)	Spare (for whole project)
TRDI 600kHz ADCP	2	1
RBR XR420 CT logger	2	1
RBR Thermistor String	1	0

2.3 MEASUREMENT LOCATION

The deployment locations of the moorings are recorded in Table 8.

Table 8 – Initial deployment locations.

Instrument	Latitude (°S)	Longitude (°E)
10m ADCP and RBR logger.	33.6701	18.4150
30m ADCP and RBR logger and Thermistor string	33.6757	18.3898

3. OPERATIONS

3.1 SUMMARY OF EVENTS.

February 7th 2009.
Recovery of the 10m and 30m ADCPs as well as the RBR-CT loggers that was attached on the respective frames was undertaken.

February 8th 2009.
Redeployment of all the instruments was successful. A new thermistor String was deployed.

3.2 INSTRUMENT CONFIGURATIONS

The deployed instrumentation configurations are given in this section and completed deployment / recovery sheets are given as an appendix (Section 7, page 51) to this report.

3.2.1 600kHz ADCP

Table 9 – Instrument configuration for the 10m ADCP.

Parameter	Configuration
ADCP model	600kHz
ADCP serial number	10841
Wave burst duration	40 min
Time between wave bursts	60min
Number of bins	42
Bin size	0.35
Sampling/ ensemble interval	10min
Pings per ensemble	500

Table 10 – Instrument configuration for the 30m ADCP.

Parameter	Configuration
ADCP model	600KHz WH ADCP
ADCP serial number	10119
Wave burst duration	40 min
Time between wave bursts	60 min
Number of bins	42
Bin size	0.5 m
Sampling/ ensemble interval	10 minutes
Pings per ensemble	500

3.2.2 RBR XR420 CT LOGGER

Table 11 – Instrument configuration for T&C Mooring Line.

Parameter	Configuration
XR 420 Temperature and Conductivity	s/n 12995 (10m) and s/n 12997 (30m)
Sampling and Averaging	Sample at 1Hz for 1 minute every 10 minutes

3.2.3 Biofouling Mooring

Table 12 – Instrument configuration for Biofouling Mooring Line.

Parameter	Configuration
Biofouling Plates	3 plates (20cmx20cm) at 3m and 3 plates (20cmx20cm) at 8m
Edgetech Acoustic Release	s/n 32385 release code 642102

3.3 RECOVER AND REDEPLOYMENT METHODOLOGY

3.3.1 T&C mooring and Thermistor string

The T&C mooring line was deployed by lowering the array down via a rope through the anchor weights. The mooring line is recovered using divers to undo a single shackle that connects the mooring line to the anchor weights. Divers reattach the line onto the weights, after the instruments have been serviced.

The Thermister string is attached to the 30m ADCP frame. The string comprises of four nodes at 30m, 29m, 19m, and 9m below the surface.

3.3.2 ADCP mooring

The ADCP Frame is lowered to the bottom and moved into position by divers, who also attach chain sections that act as anchors. To retrieve the frame divers have to locate the mooring, take off the anchor chains and surface the frame using air lift bags that they attach.

Figure 2 – ADCP frame with 600KHz instrument.

3.3.3 Biofouling mooring

The biofouling mooring line was deployed by lowering the array down via a rope through the anchor weights. Divers would locate the mooring line and retrieve a surface and bottom plate from the line at the required sampling periods.

4. DATA QUALITY CONTROL

4.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

4.1.1 Current processing

- The record was truncated to exclude times pre and post deployment as well for Dec 18 – 19th'’s service visit when the instruments were out of the water.
- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 16 W (both ADCP sites).
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP’s pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of 0.2ms^{-1} was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined.
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

4.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 16’ W (both ADCP sites).
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

The instruments were recovered, serviced and redeployed on December 18 – 19th 2008.

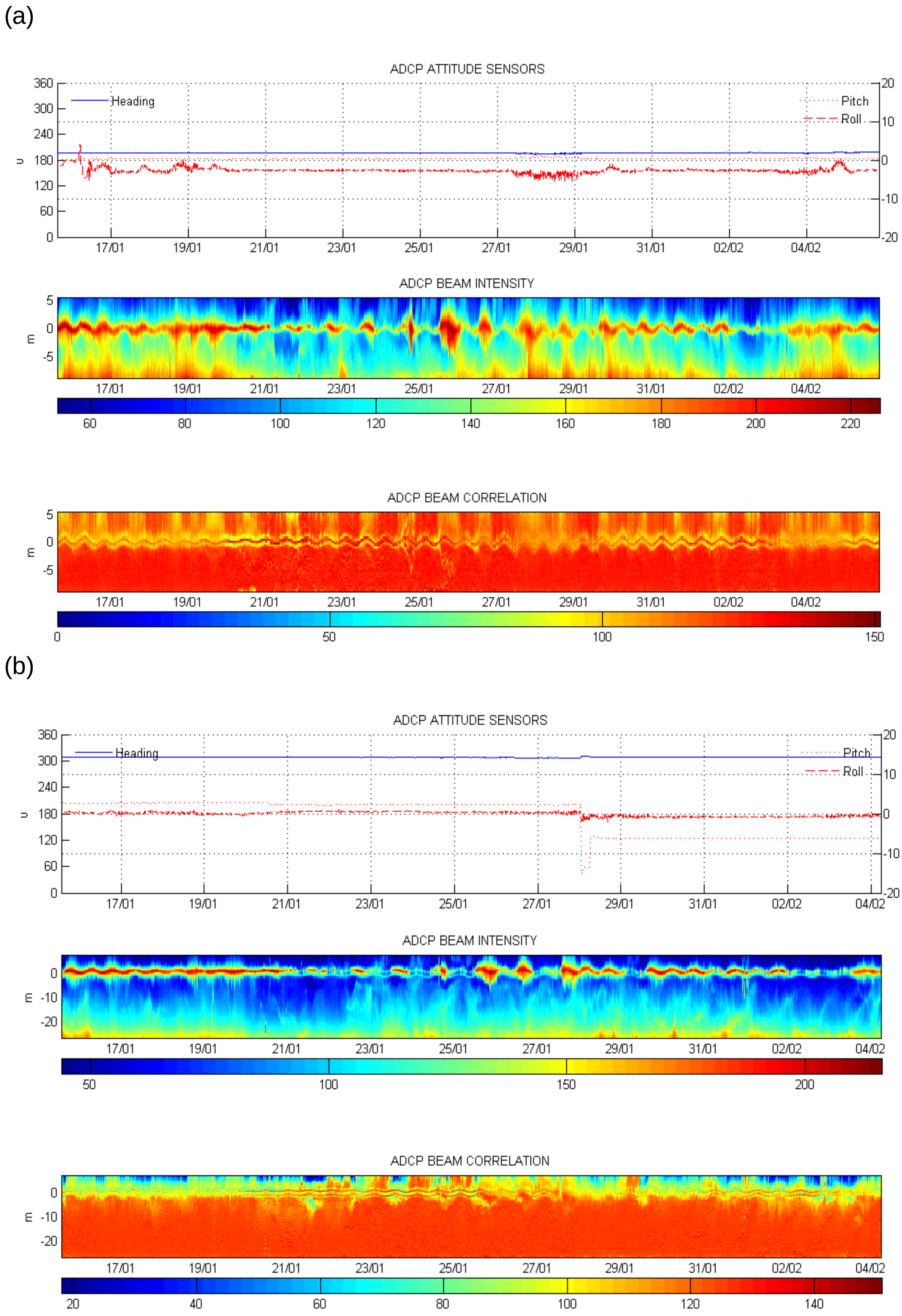


Figure 3: Quality control data from the (a) 10m and (b) 30m ADCPs. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

4.2 RBR-CT LOGGER AND THERMISTER STRING

The conductivity (from the CT-logger) and temperature data were exported directly from the RBR software into Matlab for further processing.

- The record was truncated to exclude times pre and post deployment as well for Dec 18 – 19th's service visit when the instruments were out of the water.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.
- Salinity less than 33 psu were discarded for the 30m instrument.

4.3 BIOFOULING.

The following standard procedure is normally followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates is measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 $CaCO_3$ chips are added.
- Sample bottles are stored upright in the dark.

Recovery of the biofouling plates was not scheduled.

4.4 WATER SAMPLE.

Water samples were not collected.

5. DATA PRESENTATION

All data presented have been subject to the quality control procedures detailed in the previous section. Bad data have been excluded from all plots and calculations.

All plots in this section include a stamp that details the location, depth, time period and number of observations that the plot is based upon. Wherever possible, scaling of parameters has been kept constant throughout this section to facilitate comparison between plots and stations.

5.1 10M ADCP

5.1.1 Current Data

5.1.1.1 <u>Time series plot</u>

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

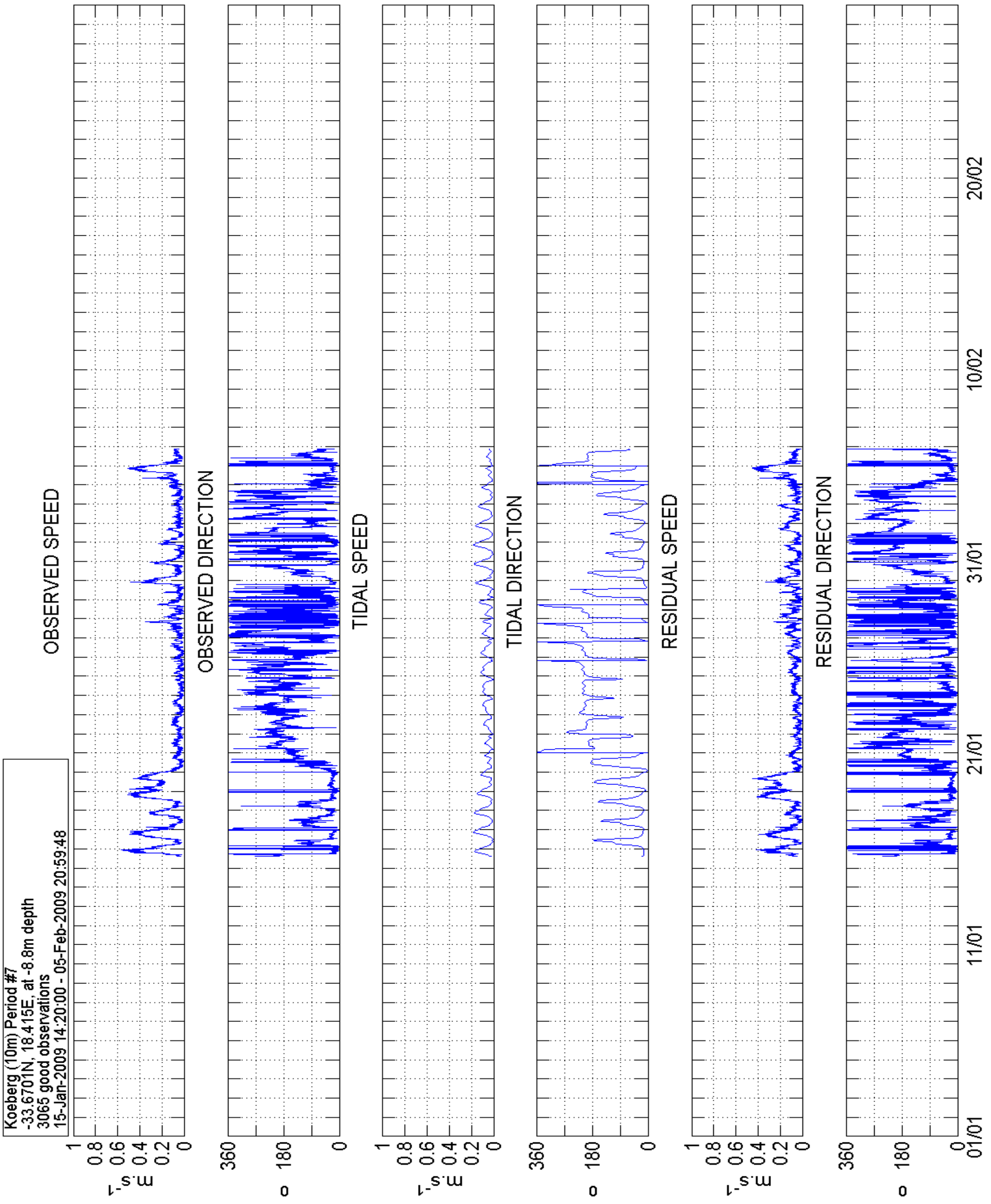


Figure 4: Time series plot of the 10m ADCP's current data at 8.8m.

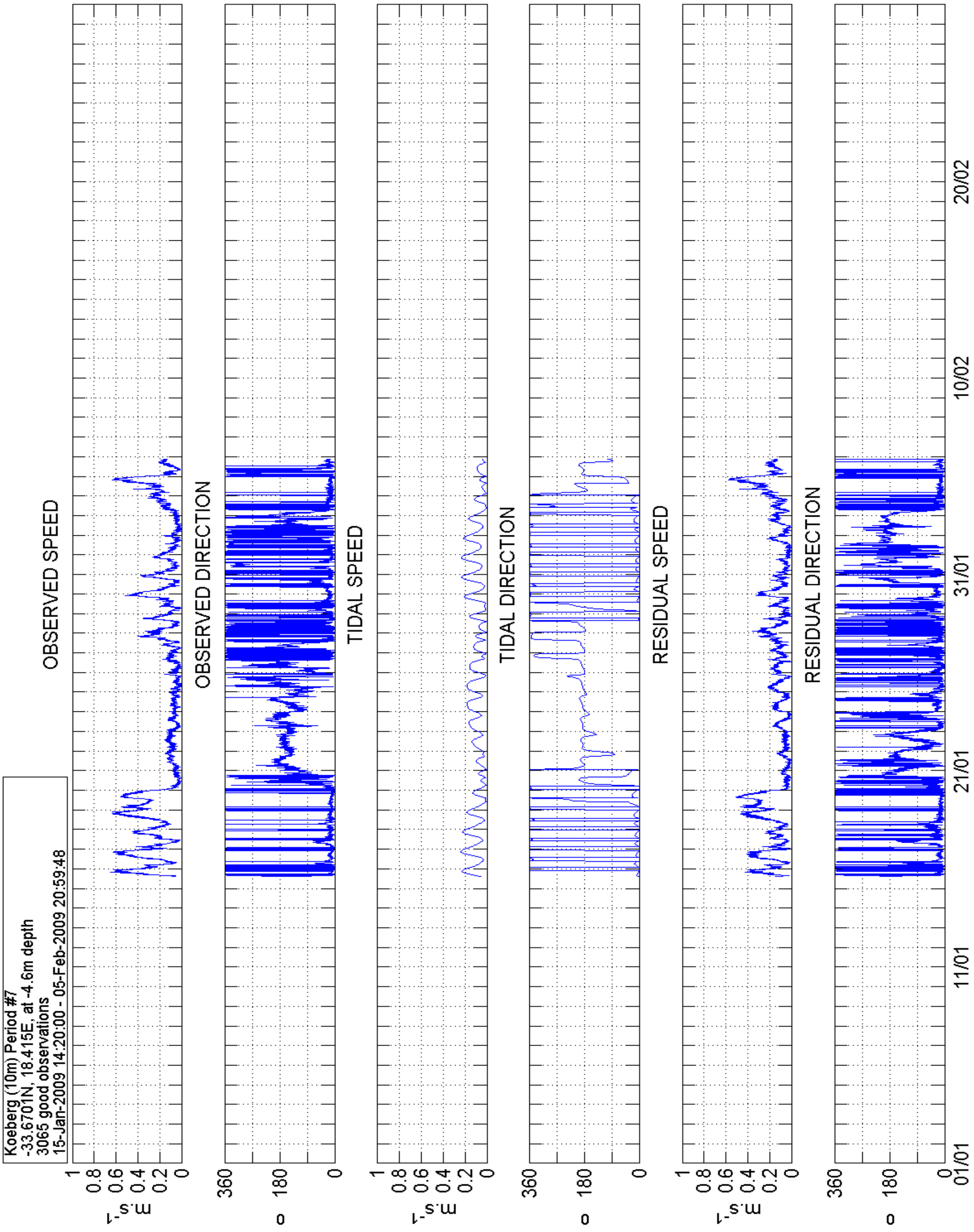


Figure 5: Time series plot of the 10m ADCP's current data at 4.6m.

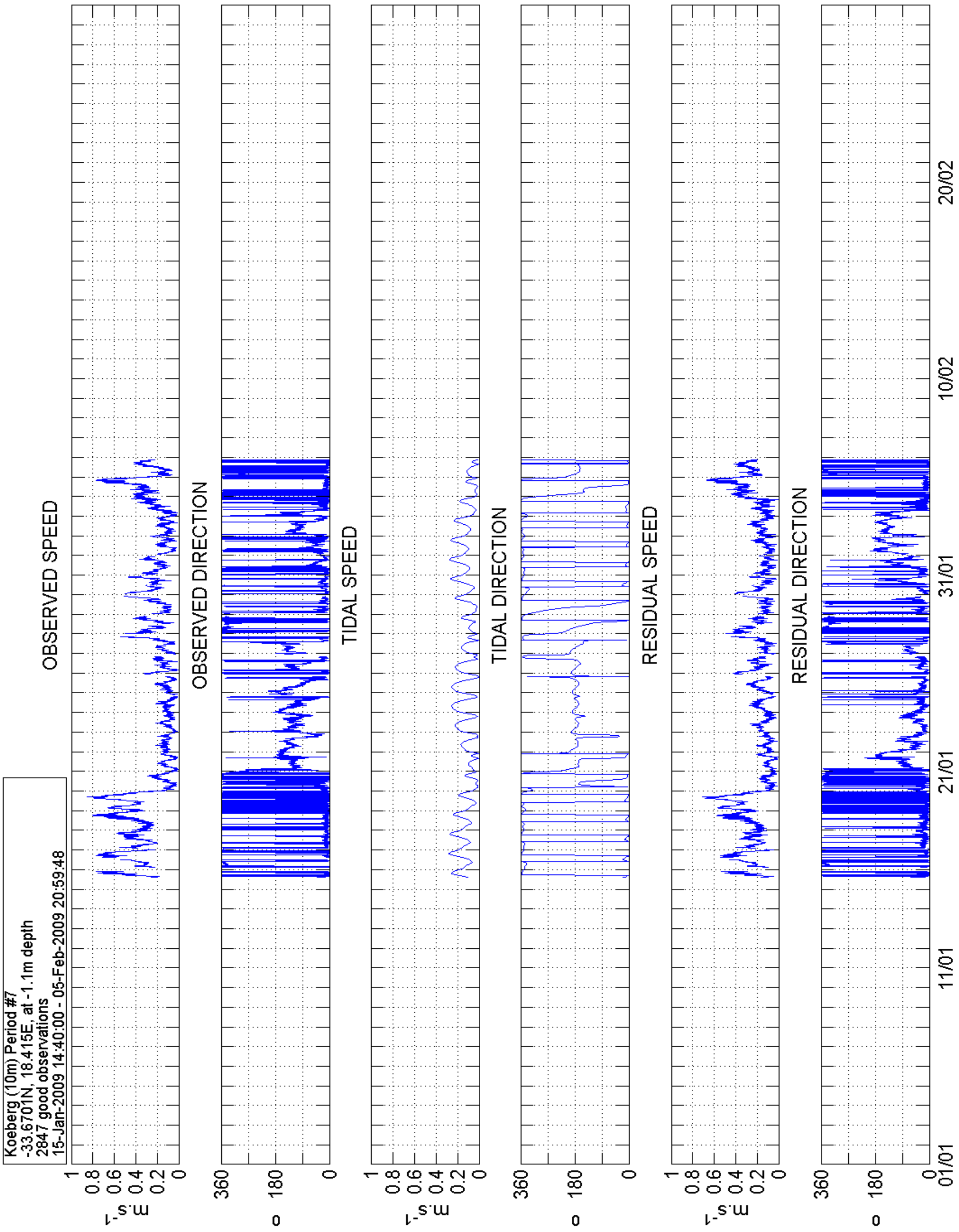
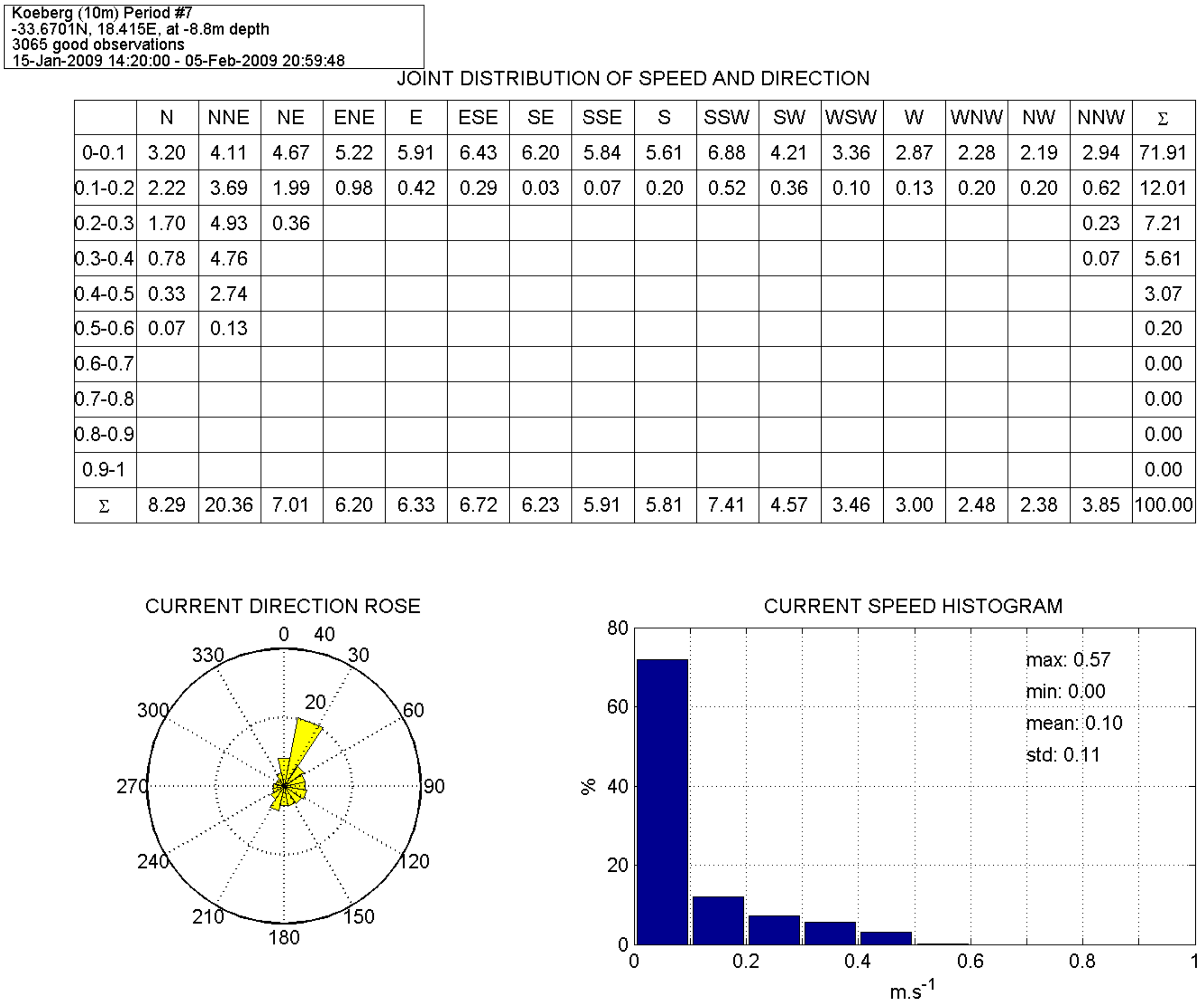


Figure 6: Time series plot of the 10m ADCP's current data at 1.1m.

5.1.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.



Koeberg (10m) Period #7
-33.6701N, 18.415E, at -8.8m depth
3065 good observations
15-Jan-2009 14:20:00 - 05-Feb-2009 20:59:48

JOINT DISTRIBUTION OF SPEED AND DIRECTION

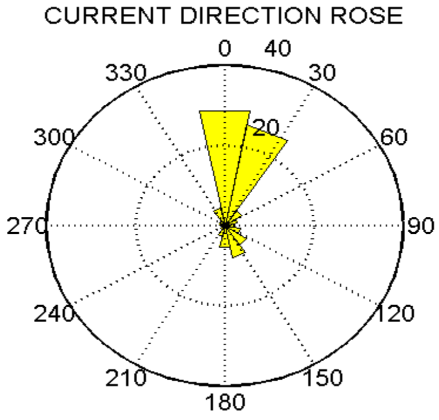
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	3.20	4.11	4.67	5.22	5.91	6.43	6.20	5.84	5.61	6.88	4.21	3.36	2.87	2.28	2.19	2.94	71.91
0.1-0.2	2.22	3.69	1.99	0.98	0.42	0.29	0.03	0.07	0.20	0.52	0.36	0.10	0.13	0.20	0.20	0.62	12.01
0.2-0.3	1.70	4.93	0.36													0.23	7.21
0.3-0.4	0.78	4.76														0.07	5.61
0.4-0.5	0.33	2.74															3.07
0.5-0.6	0.07	0.13															0.20
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	8.29	20.36	7.01	6.20	6.33	6.72	6.23	5.91	5.81	7.41	4.57	3.46	3.00	2.48	2.38	3.85	100.00

Figure 7: Summary plot of the 10m ADCP's current data at 8.8m.

Koeberg (10m) Period #7
-33.6701N, 18.415E, at -4.6m depth
3065 good observations
15-Jan-2009 14:20:00 - 05-Feb-2009 20:59:48

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	6.30	5.09	3.69	2.77	2.28	3.39	4.70	6.20	4.27	2.35	1.11	0.82	0.52	1.11	1.31	2.32	48.22
0.1-0.2	7.70	8.45	0.85	0.13	0.07	0.23	1.21	1.96	1.31	0.49		0.03	0.13	0.03	0.07	1.60	24.24
0.2-0.3	6.43	4.76	0.10												0.03	0.20	11.52
0.3-0.4	4.01	2.77														0.20	6.98
0.4-0.5	2.54	2.19														0.03	4.76
0.5-0.6	1.60	1.96															3.56
0.6-0.7	0.42	0.29															0.72
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	29.00	25.51	4.63	2.90	2.35	3.62	5.91	8.16	5.58	2.84	1.11	0.85	0.65	1.14	1.40	4.34	100.00



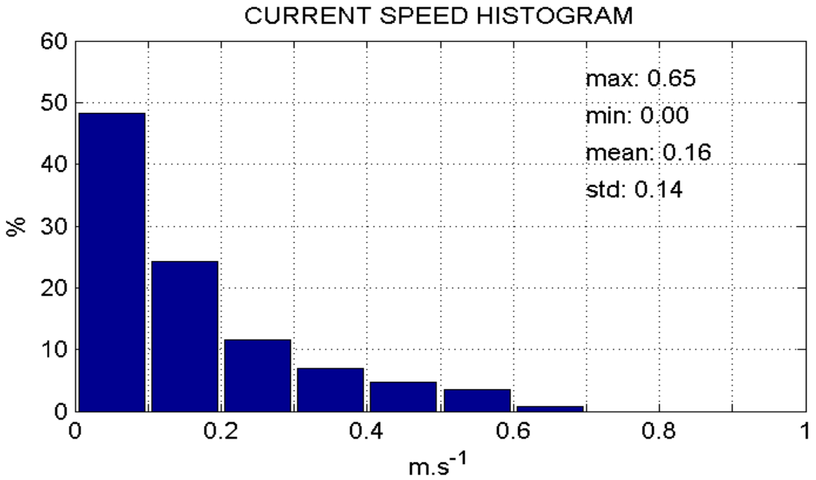
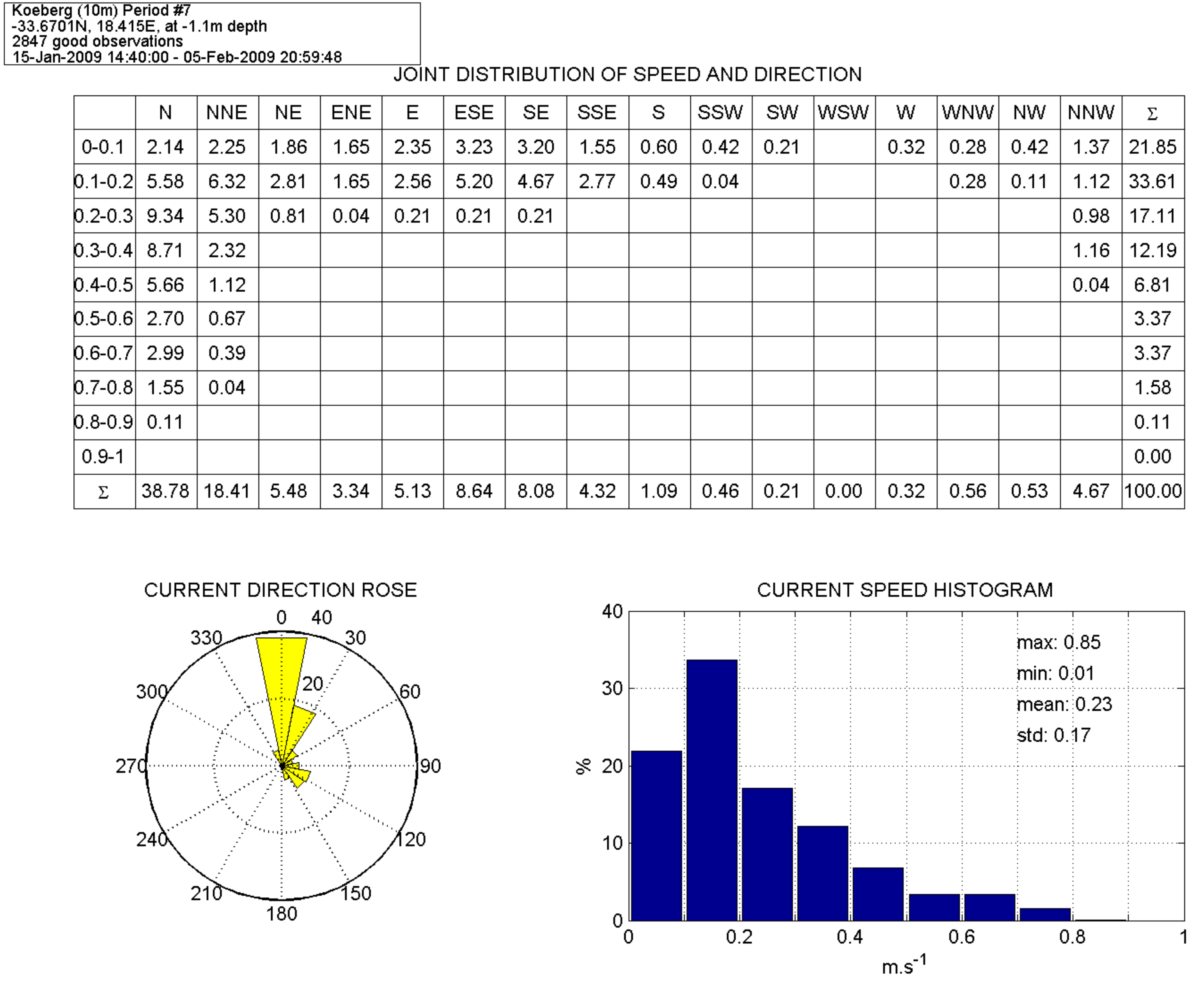


Figure 8: Summary plot of the 10m ADCP's current data at 4.6m.



Koeberg (10m) Period #7
-33.6701N, 18.415E, at -1.1m depth
2847 good observations
15-Jan-2009 14:40:00 - 05-Feb-2009 20:59:48

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	2.14	2.25	1.86	1.65	2.35	3.23	3.20	1.55	0.60	0.42	0.21		0.32	0.28	0.42	1.37	21.85
0.1-0.2	5.58	6.32	2.81	1.65	2.56	5.20	4.67	2.77	0.49	0.04				0.28	0.11	1.12	33.61
0.2-0.3	9.34	5.30	0.81	0.04	0.21	0.21	0.21									0.98	17.11
0.3-0.4	8.71	2.32														1.16	12.19
0.4-0.5	5.66	1.12														0.04	6.81
0.5-0.6	2.70	0.67															3.37
0.6-0.7	2.99	0.39															3.37
0.7-0.8	1.55	0.04															1.58
0.8-0.9	0.11																0.11
0.9-1																	0.00
Σ	38.78	18.41	5.48	3.34	5.13	8.64	8.08	4.32	1.09	0.46	0.21	0.00	0.32	0.56	0.53	4.67	100.00

Figure 9: Summary plot of the 10m ADCP's current data at 1.1m.

5.1.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

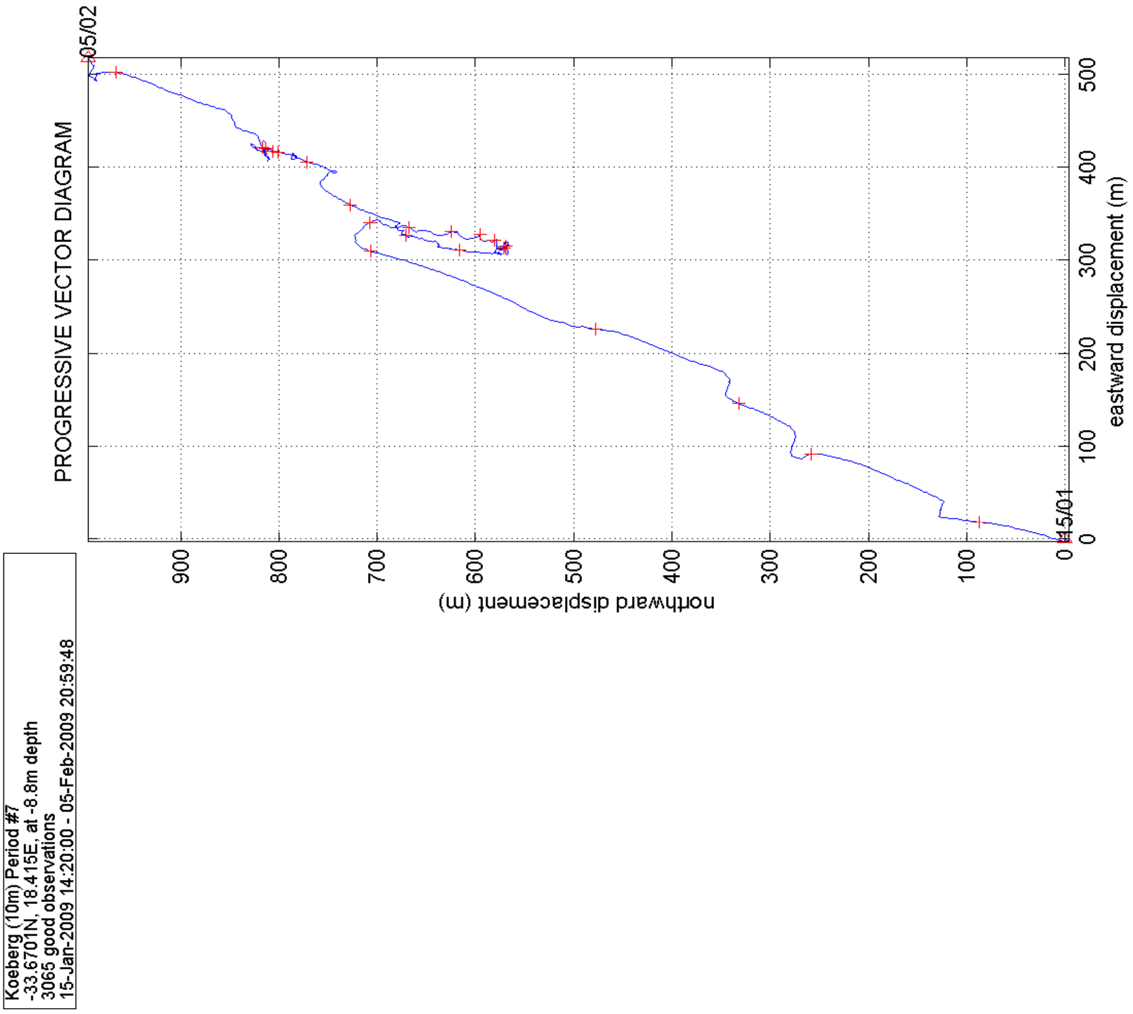


Figure 10: Progressive vector plot of current data at 8.8m.

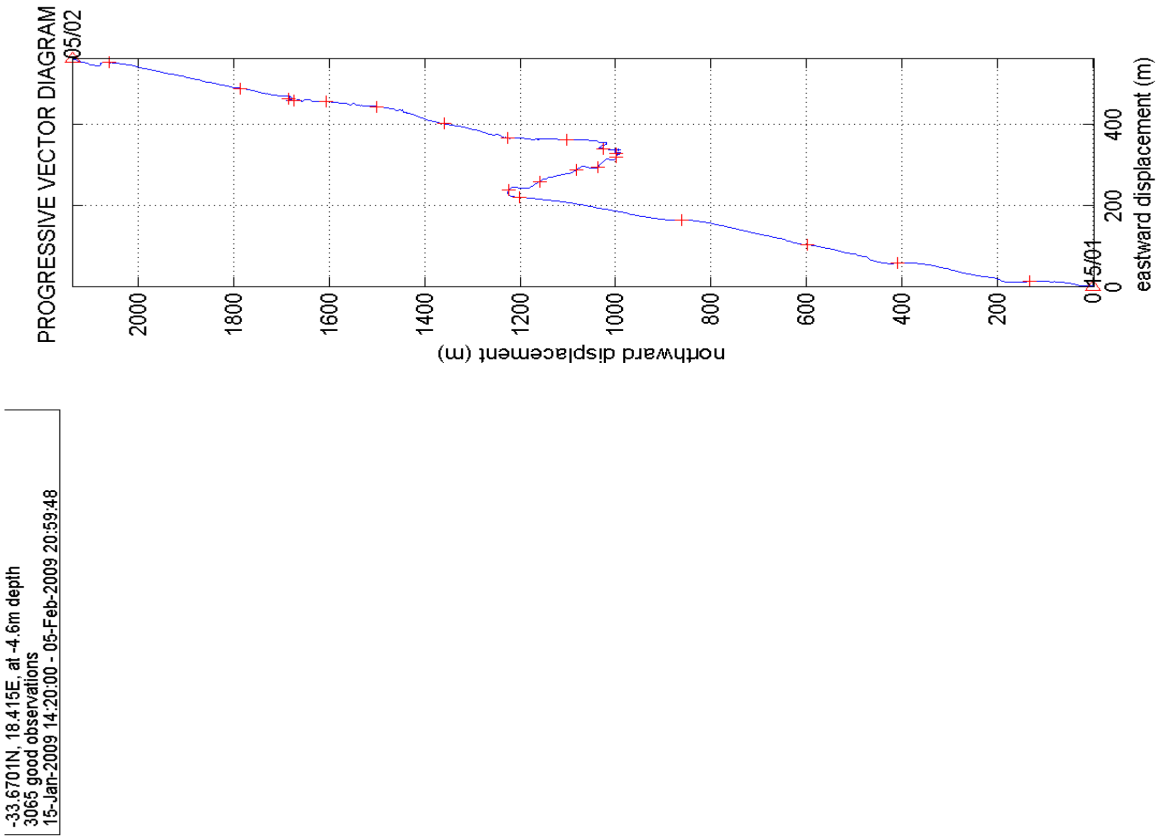


Figure 11: Progressive vector plot of current data at 4.6m.

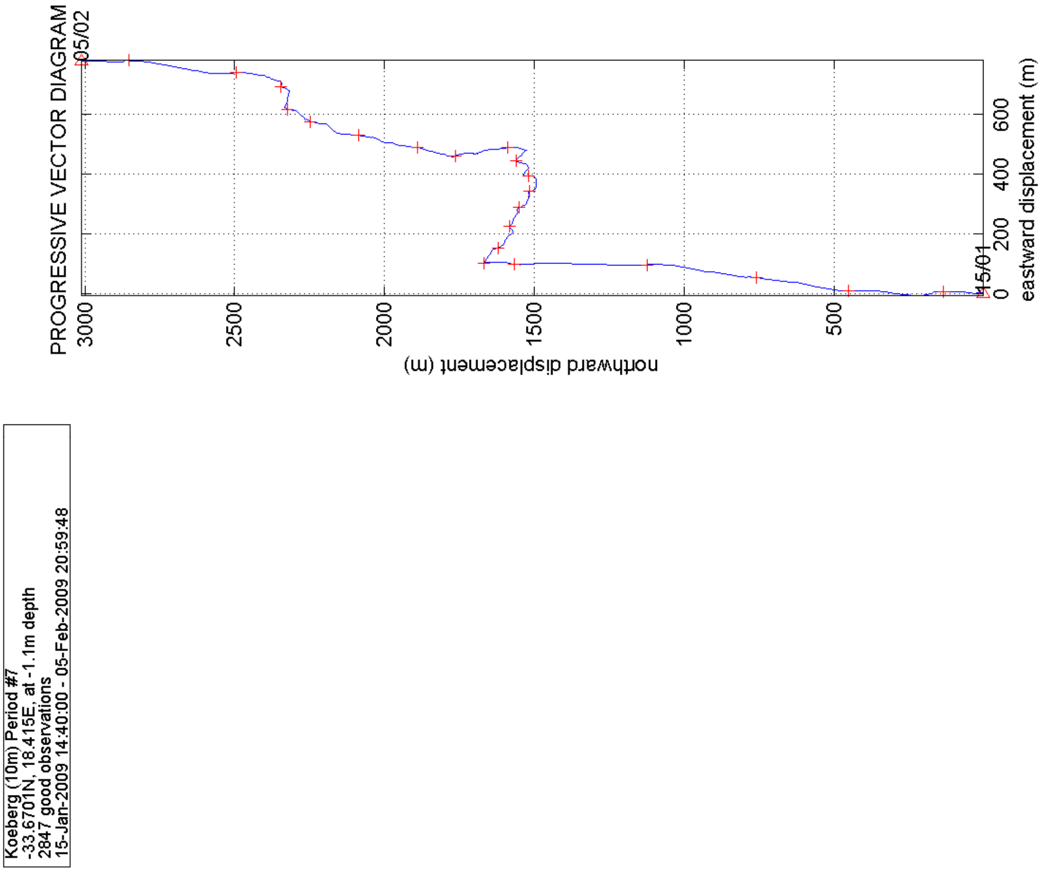


Figure 12: Progressive vector plot of current data at 1.1m.

5.1.2 Wave Data.

5.1.2.1 Hs and Tp summary plot

Figure 13 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.1.2.2 Hs and Dp summary plot

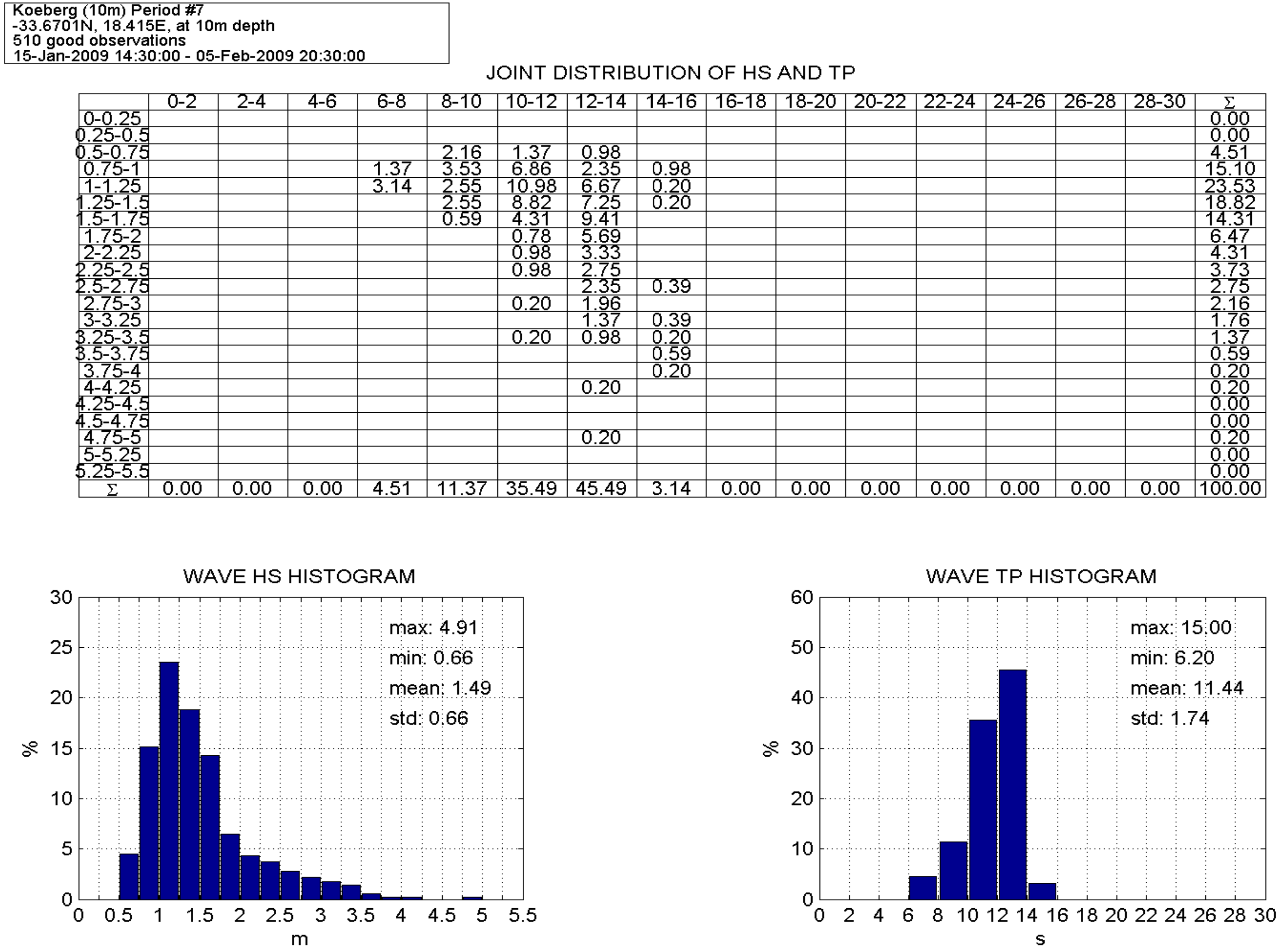
Figure 14 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.1.2.3 Tp and Dp summary plot

Figure 15 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.



Koeberg (10m) Period #7
-33.6701N, 18.415E, at 10m depth
510 good observations
15-Jan-2009 14:30:00 - 05-Feb-2009 20:30:00

JOINT DISTRIBUTION OF HS AND TP

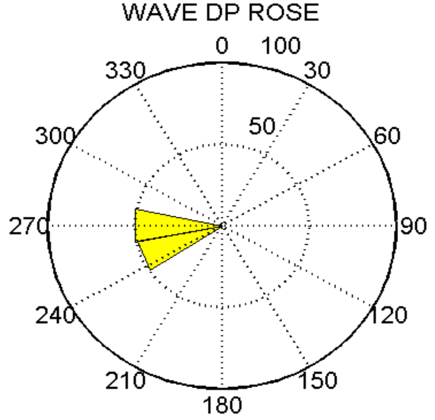
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5																0.00
0.5-0.75					2.16	1.37	0.98									4.51
0.75-1				1.37	3.53	6.86	2.35	0.98								15.10
1-1.25				3.14	2.55	10.98	6.67	0.20								23.53
1.25-1.5					2.55	8.82	7.25	0.20								18.82
1.5-1.75					0.59	4.31	9.41									14.31
1.75-2						0.78	5.69									6.47
2-2.25						0.98	3.33									4.31
2.25-2.5						0.98	2.75									3.73
2.5-2.75							2.35	0.39								2.75
2.75-3						0.20	1.96									2.16
3-3.25							1.37	0.39								1.76
3.25-3.5						0.20	0.98	0.20								1.37
3.5-3.75								0.59								0.59
3.75-4								0.20								0.20
4-4.25							0.20									0.20
4.25-4.5																0.00
4.5-4.75																0.00
4.75-5							0.20									0.20
5-5.25																0.00
5.25-5.5																0.00
Σ	0.00	0.00	0.00	4.51	11.37	35.49	45.49	3.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Figure 13: Summary plot of H_s and T_p.

Koeberg (10m) Period #7
-33.6701N, 18.415E, at 10m depth
510 good observations
15-Jan-2009 14:30:00 - 05-Feb-2009 20:30:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5																	0.00
0.5-0.75												1.76	2.75				4.51
0.75-1												7.84	7.25				15.10
1-1.25												10.20	13.14	0.20			23.53
1.25-1.5												7.45	11.37				18.82
1.5-1.75												9.41	4.90				14.31
1.75-2											0.20	2.55	3.73				6.47
2-2.25												2.75	1.57				4.31
2.25-2.5												2.75	0.98				3.73
2.5-2.75												1.57	1.18				2.75
2.75-3												0.39	1.76				2.16
3-3.25												1.18	0.59				1.76
3.25-3.5												0.98	0.39				1.37
3.5-3.75													0.59				0.59
3.75-4												0.20					0.20
4-4.25													0.20				0.20
4.25-4.5																	0.00
4.5-4.75																	0.00
4.75-5													0.20				0.20
5-5.25																	0.00
5.25-5.5																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	49.02	50.59	0.20	0.00	0.00	100.00



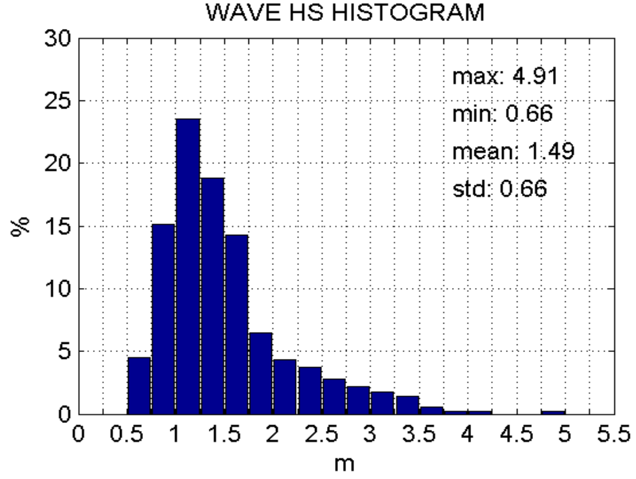
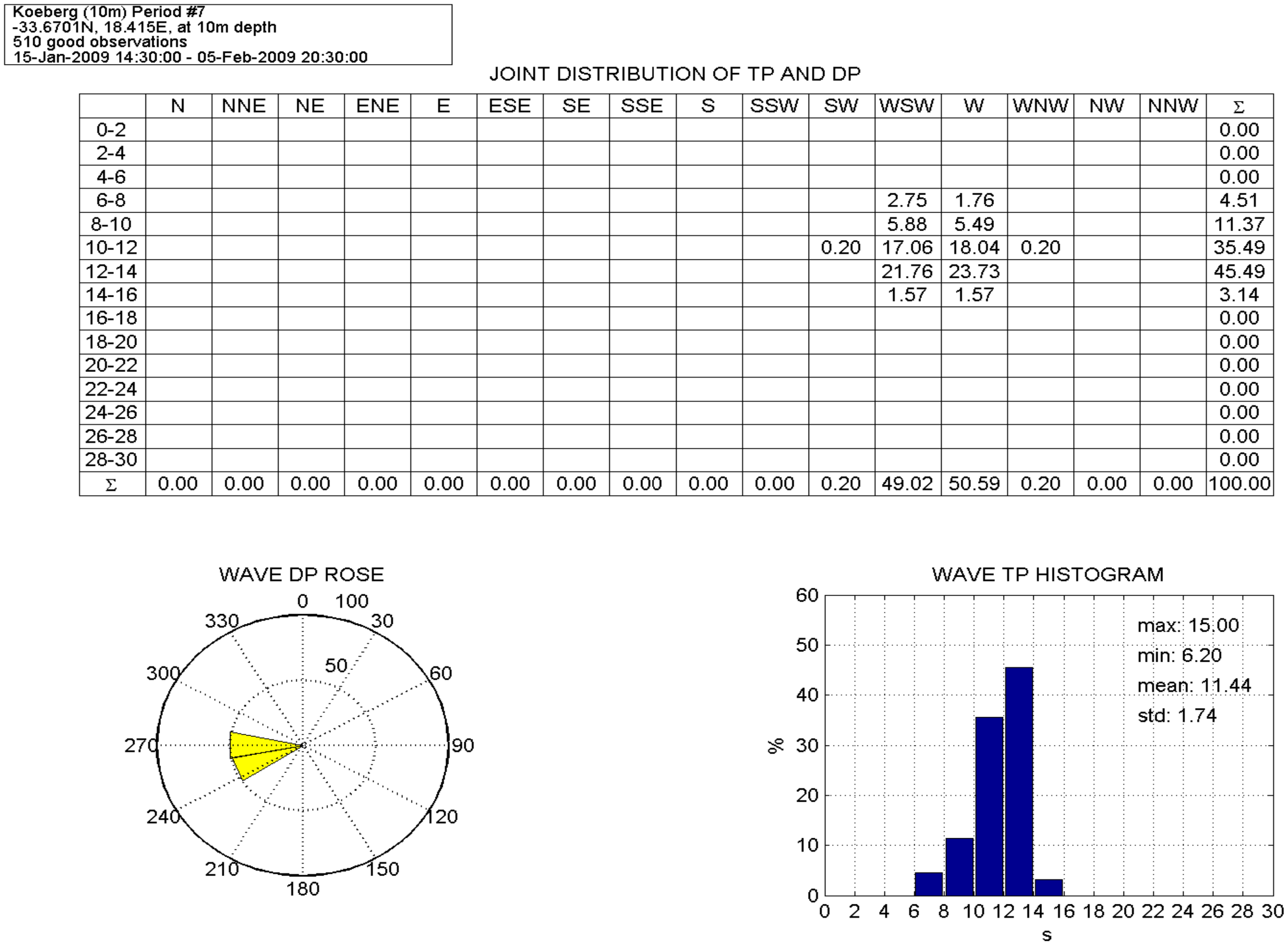


Figure 14: Summary plot of H_s and D_p.



Koeberg (10m) Period #7
-33.6701N, 18.415E, at 10m depth
510 good observations
15-Jan-2009 14:30:00 - 05-Feb-2009 20:30:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4																	0.00
4-6																	0.00
6-8												2.75	1.76				4.51
8-10												5.88	5.49				11.37
10-12											0.20	17.06	18.04	0.20			35.49
12-14												21.76	23.73				45.49
14-16												1.57	1.57				3.14
16-18																	0.00
18-20																	0.00
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	49.02	50.59	0.20	0.00	0.00	100.00

Figure 15: Summary plot of T_p and D_p.

5.1.2.4 Wave spectral plot

Figure 16 displays wave spectral plots for a significant wave event. The time of the spectrum is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

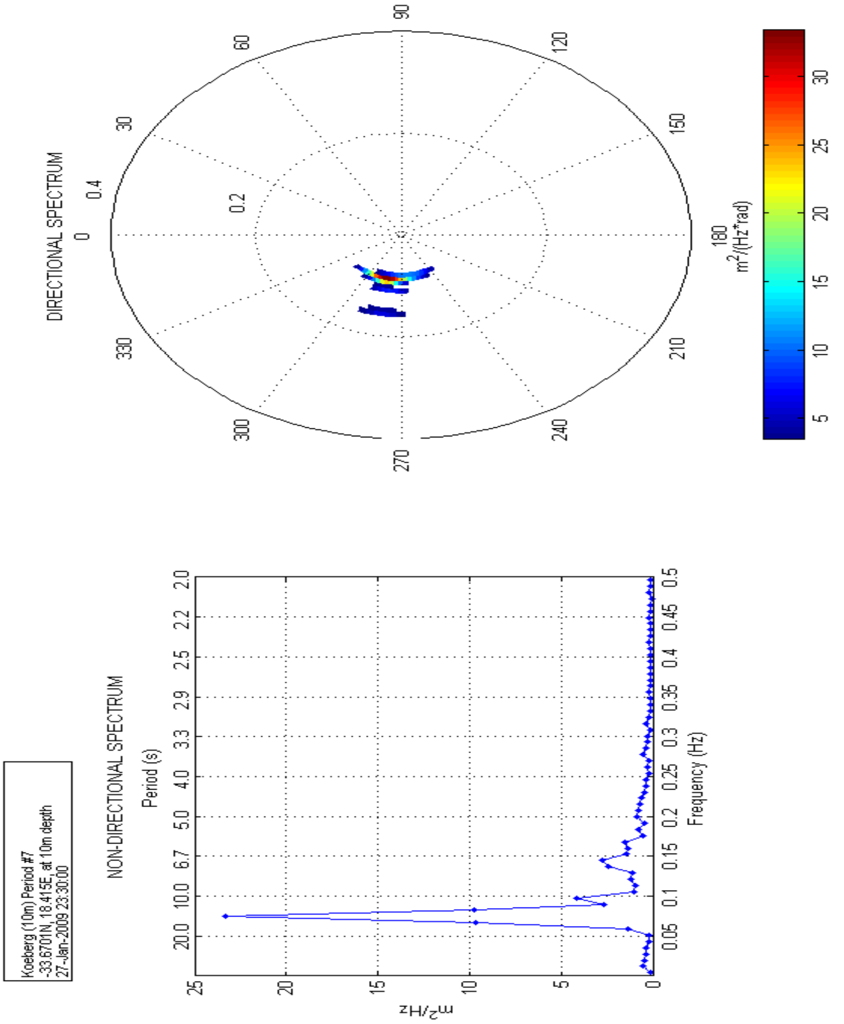


Figure 16: Wave spectra for 27th Jan 2009 at 23:30.

5.2 30M ADCP

5.2.1 Current Data

5.2.1.1 Time series plot

The figures on the following pages display time series plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The first (upper) panel is of the averaged current speed against time.
- The second panel is of the averaged current direction against time.
- The third panel is of the tidal current speed, calculated from the observed current speed and direction, against time. The entire data set of observations is used in the derivation of the tidal component. The tidal calculation follows the method of Foreman and uses the observed complex current vector as input (*R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937*)
- The fourth panel is of the tidal current direction, calculated as above, against time.
- The fifth panel is of the residual current speed against time. The residual has been calculated as north and east components (residual component = observed component – tidal component), which have then been converted into residual speed and direction.
- The sixth panel is of the residual current direction against time, calculated as above.

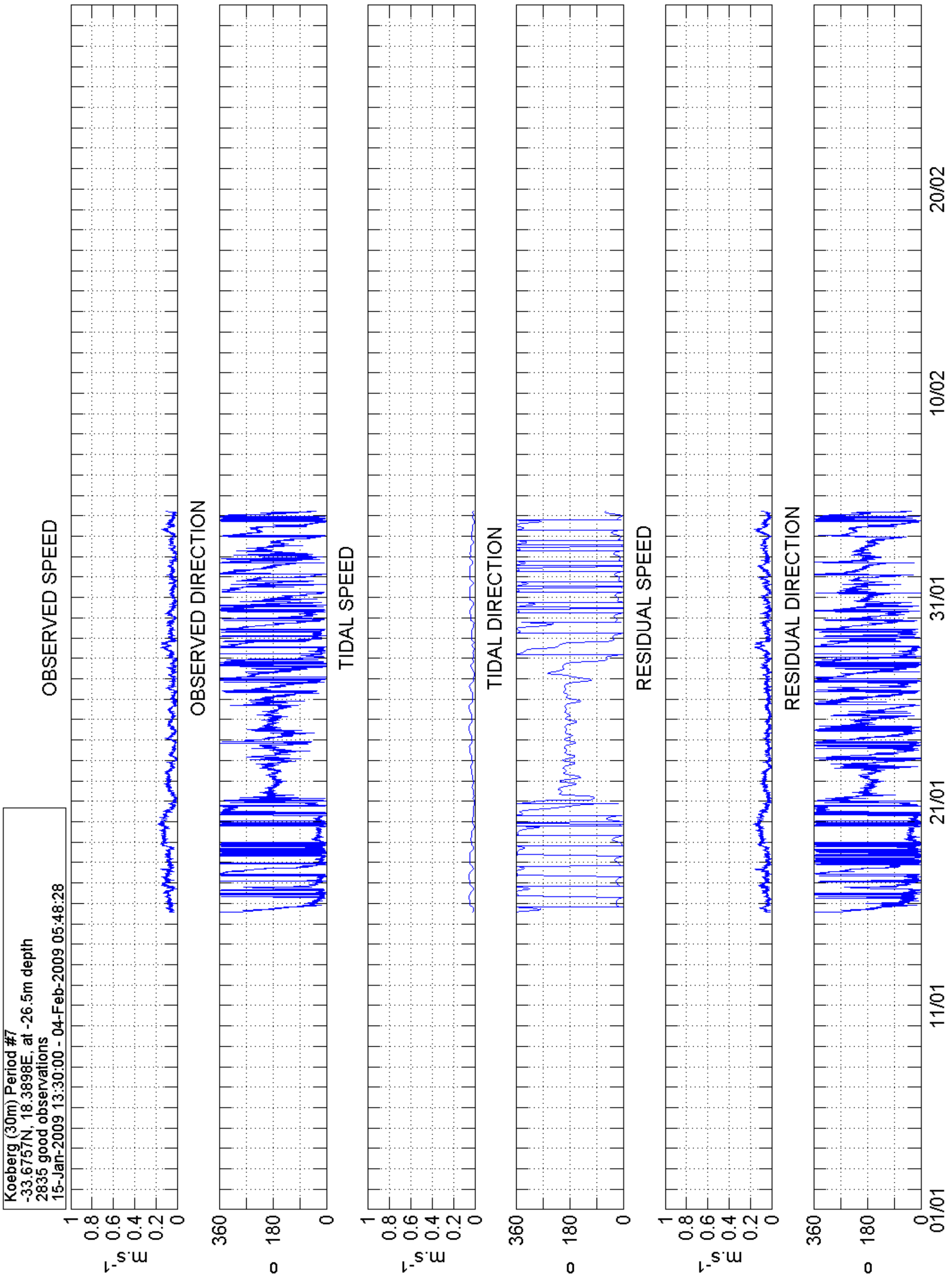


Figure 17: Time series plot of the 30m ADCP's current data at 30m.

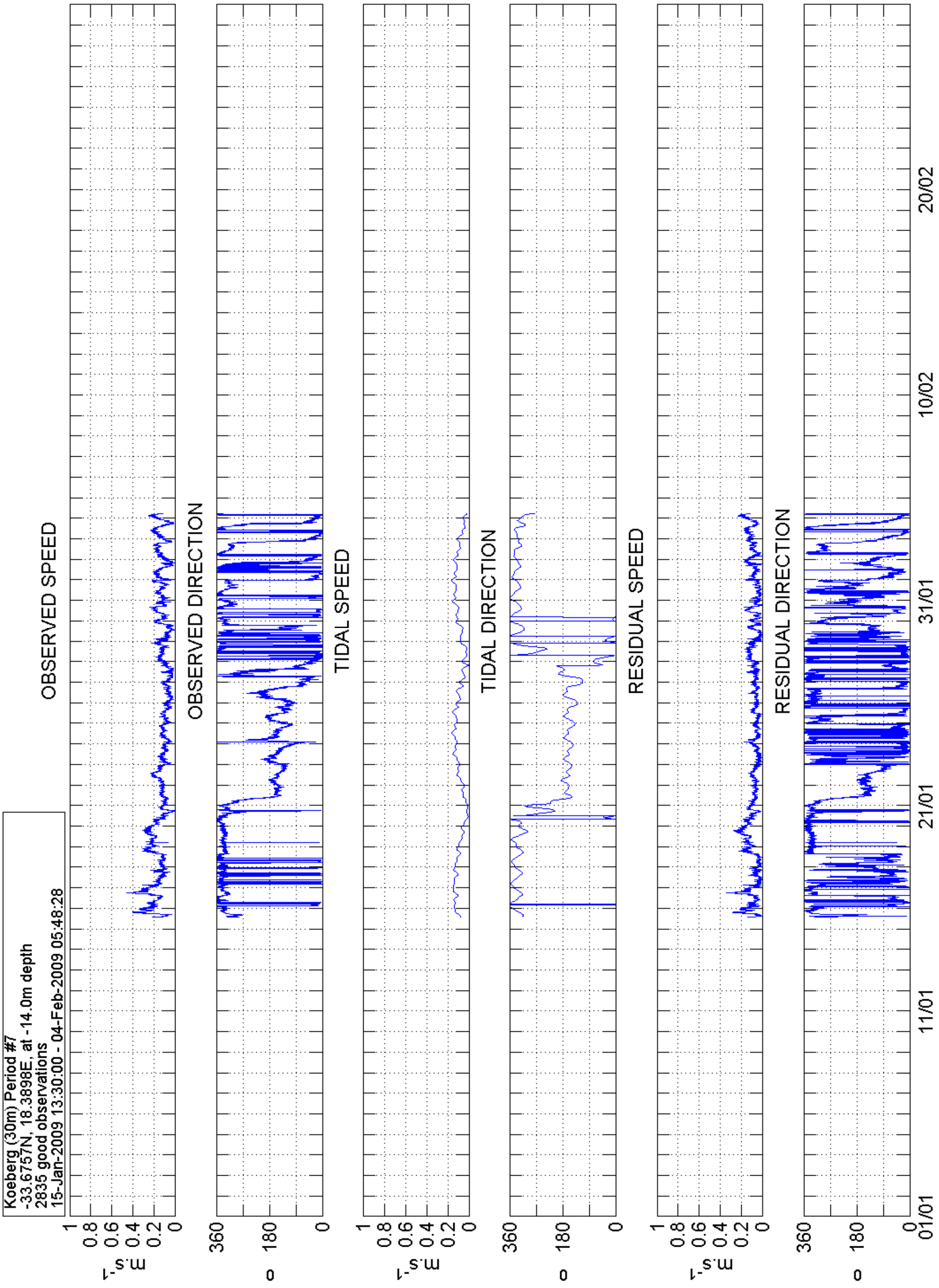


Figure 18: Time series plot of the 30m ADCP’s current data at 14.0m.

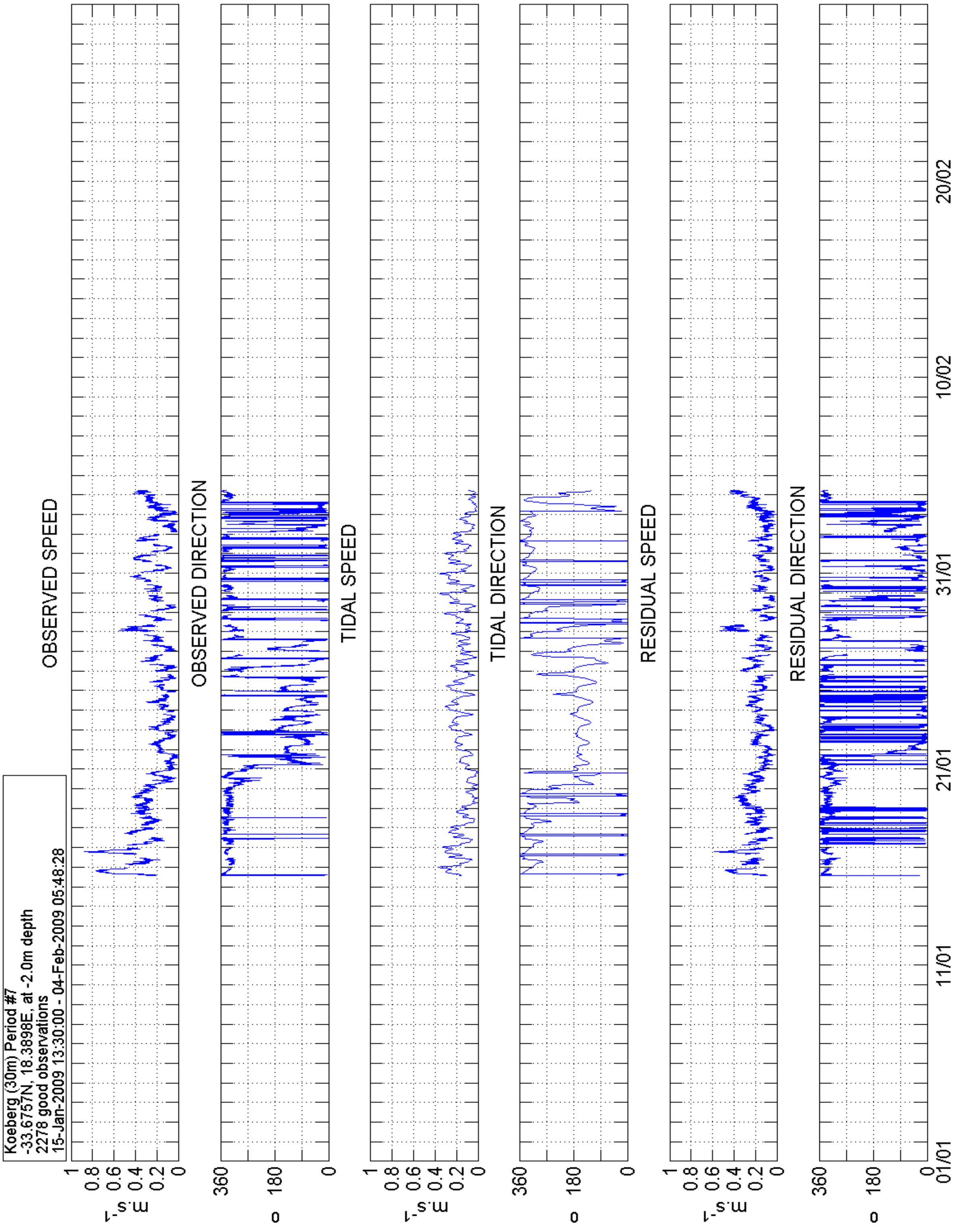
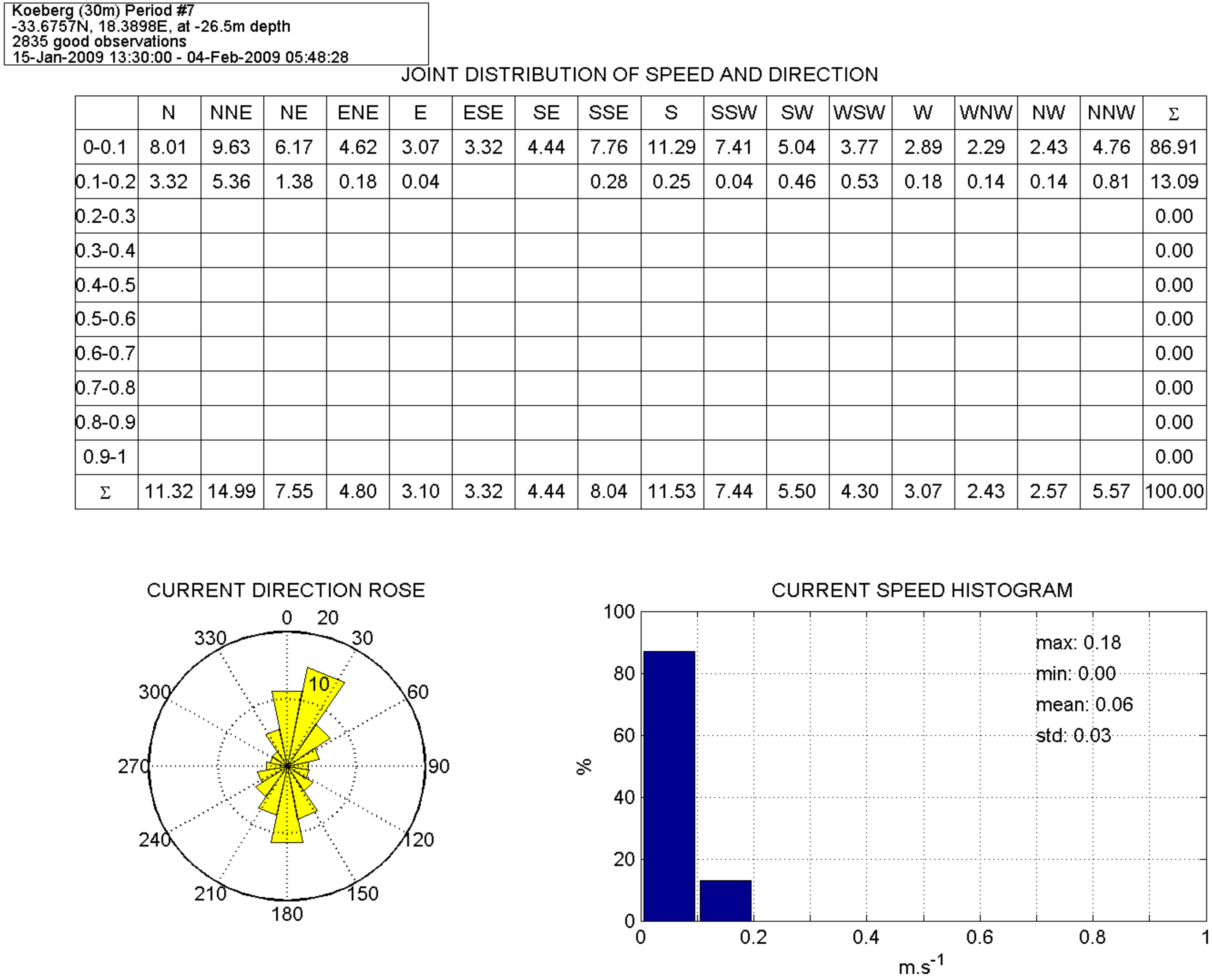


Figure 19: Time series plot of the 30m ADCP’s current data at 2.0m.

5.2.1.2 Summary plot

The figures on the following pages display summary plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The upper panel is a table of the joint distribution of 10 minute averaged current speed against direction. Columns of the table represent direction classes and rows the speed classes. The numbers in the table reflect the percentage of observations that fall within a particular speed interval and direction sector.
- The lower left hand panel is a rose of the 10 minute averaged current direction. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the 10 minute averaged current speeds. This reflects the percentage of observations that fall within each speed interval. Included on the plot are basic statistics for the current speed distribution.



Koeberg (30m) Period #7
-33.6757N, 18.3898E, at -26.5m depth
2835 good observations
15-Jan-2009 13:30:00 - 04-Feb-2009 05:48:28

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	8.01	9.63	6.17	4.62	3.07	3.32	4.44	7.76	11.29	7.41	5.04	3.77	2.89	2.29	2.43	4.76	86.91
0.1-0.2	3.32	5.36	1.38	0.18	0.04			0.28	0.25	0.04	0.46	0.53	0.18	0.14	0.14	0.81	13.09
0.2-0.3																	0.00
0.3-0.4																	0.00
0.4-0.5																	0.00
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	11.32	14.99	7.55	4.80	3.10	3.32	4.44	8.04	11.53	7.44	5.50	4.30	3.07	2.43	2.57	5.57	100.00

Figure 20: Summary plot of the 30m ADCP's current data at 26.5m.

Koeberg (30m) Period #7
-33.6757N, 18.3898E, at -14.0m depth
2835 good observations
15-Jan-2009 13:30:00 - 04-Feb-2009 05:48:28

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	2.36	1.76	2.54	2.47	1.41	2.26	3.63	2.50	2.47	1.87	0.95	1.20	1.48	1.83	2.22	2.15	33.12
0.1-0.2	13.09	5.71	1.06	0.63	0.18	1.20	3.88	6.88	2.15	0.07		0.04	0.07	1.16	5.11	12.70	53.93
0.2-0.3	1.38	0.53	0.04				0.07	0.71						0.04	1.38	7.48	11.60
0.3-0.4															0.32	0.88	1.20
0.4-0.5															0.07	0.07	0.14
0.5-0.6																	0.00
0.6-0.7																	0.00
0.7-0.8																	0.00
0.8-0.9																	0.00
0.9-1																	0.00
Σ	16.83	8.01	3.63	3.10	1.59	3.46	7.58	10.09	4.62	1.94	0.95	1.23	1.55	3.03	9.10	23.28	100.00

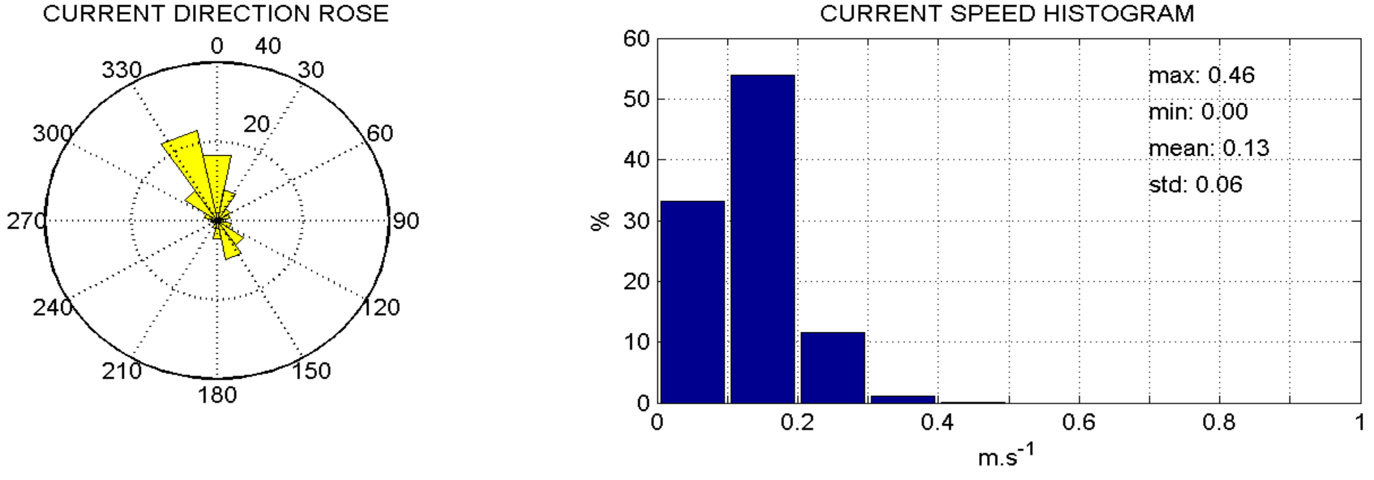
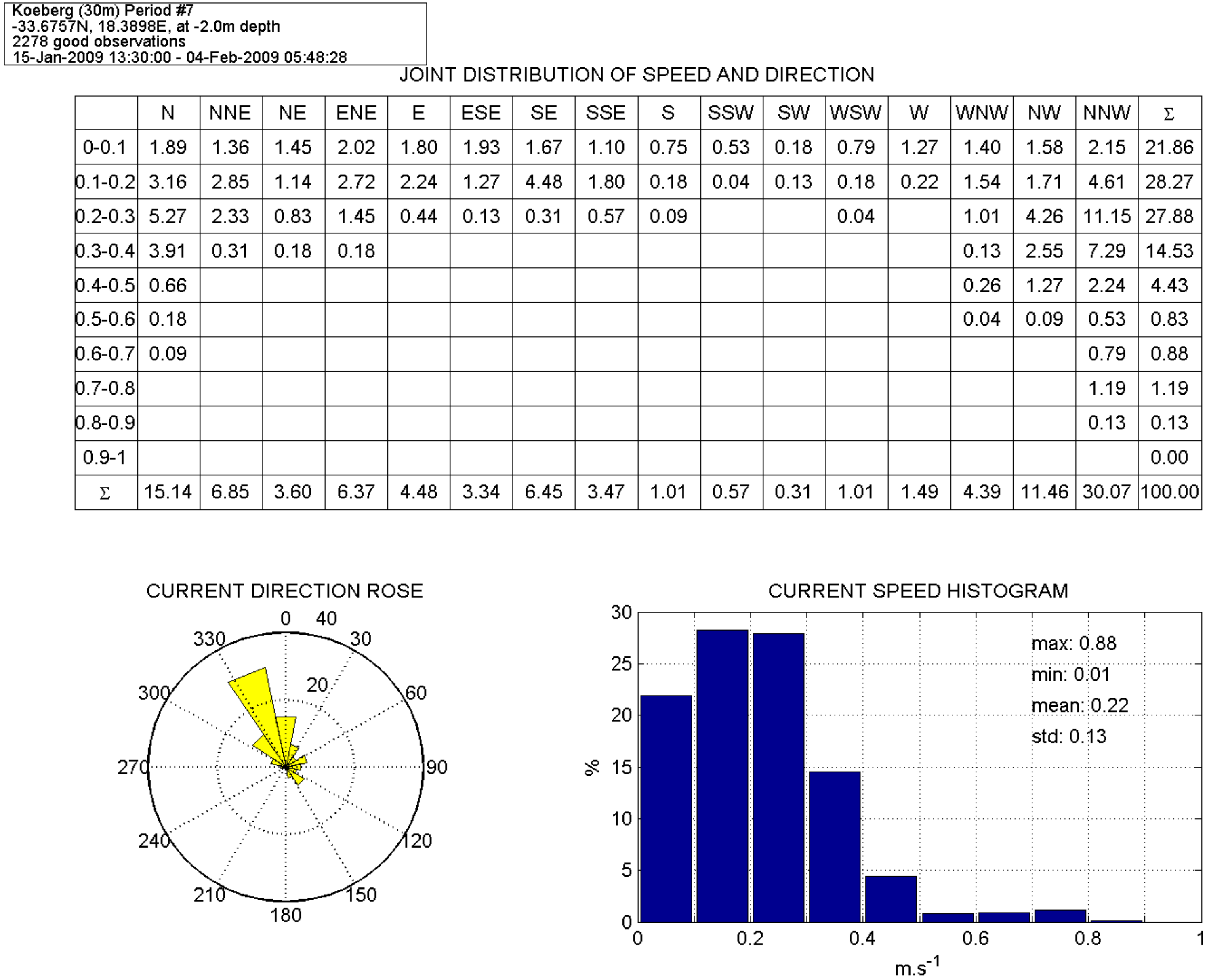


Figure 21: Summary plot of the 30m ADCP’s current data at 14.7m.



Koeberg (30m) Period #7
-33.6757N, 18.3898E, at -2.0m depth
2278 good observations
15-Jan-2009 13:30:00 - 04-Feb-2009 05:48:28

JOINT DISTRIBUTION OF SPEED AND DIRECTION

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.1	1.89	1.36	1.45	2.02	1.80	1.93	1.67	1.10	0.75	0.53	0.18	0.79	1.27	1.40	1.58	2.15	21.86
0.1-0.2	3.16	2.85	1.14	2.72	2.24	1.27	4.48	1.80	0.18	0.04	0.13	0.18	0.22	1.54	1.71	4.61	28.27
0.2-0.3	5.27	2.33	0.83	1.45	0.44	0.13	0.31	0.57	0.09			0.04		1.01	4.26	11.15	27.88
0.3-0.4	3.91	0.31	0.18	0.18										0.13	2.55	7.29	14.53
0.4-0.5	0.66													0.26	1.27	2.24	4.43
0.5-0.6	0.18													0.04	0.09	0.53	0.83
0.6-0.7	0.09															0.79	0.88
0.7-0.8																1.19	1.19
0.8-0.9																0.13	0.13
0.9-1																	0.00
Σ	15.14	6.85	3.60	6.37	4.48	3.34	6.45	3.47	1.01	0.57	0.31	1.01	1.49	4.39	11.46	30.07	100.00

Figure 22: Summary plot of the 30m ADCP's current data at 2.0m.

5.2.1.3 Progressive vector plot

The figures on the following pages display progressive vector plots for depths representing near-bottom, mid-depth and near-surface flow respectively. These plots consist of:

- The solid line represents the displacement that a particle of water would undergo when subject to the currents that were observed.
- The start and end points of the observations are labelled.
- Each day is represented by a red cross.

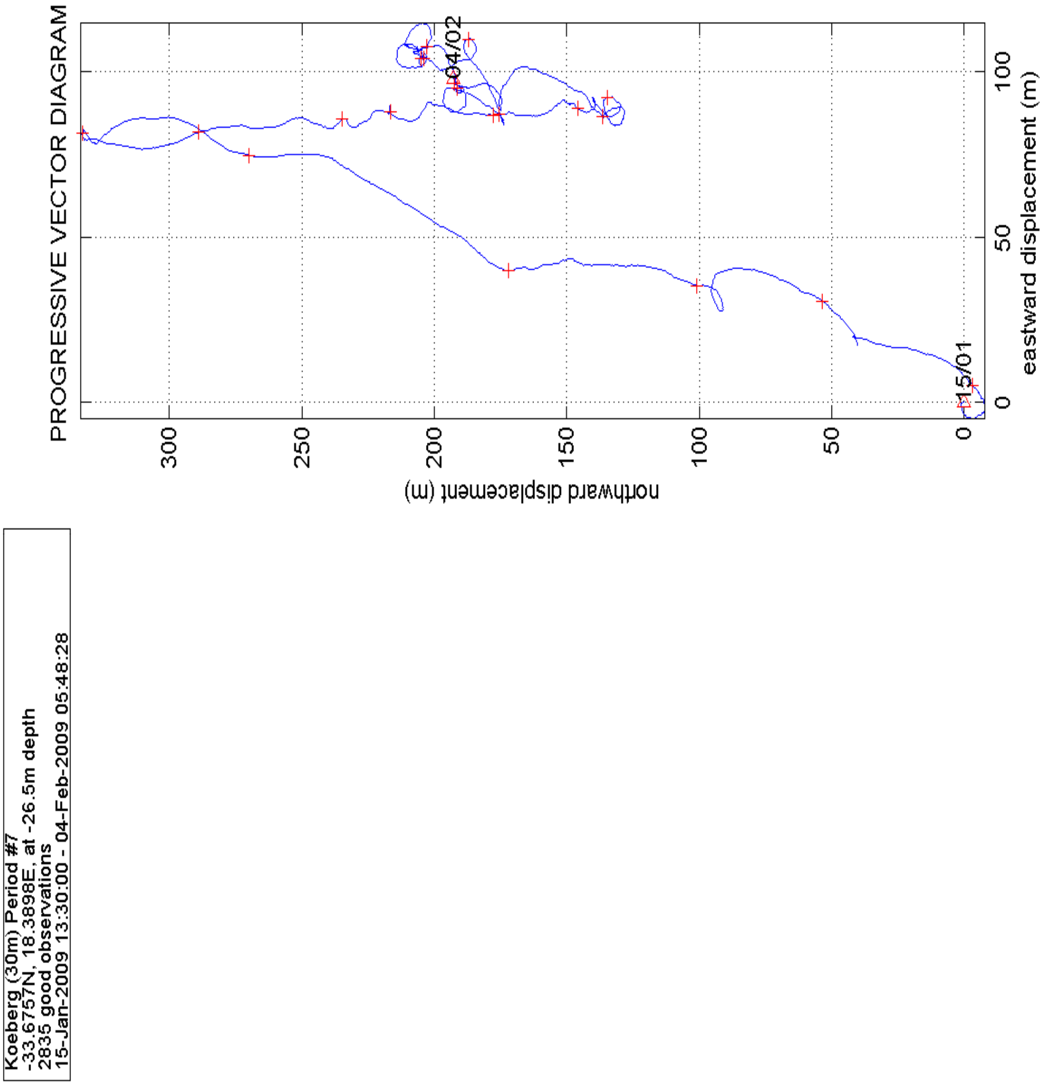


Figure 23: Progressive vector plot of current data at 26.5m.

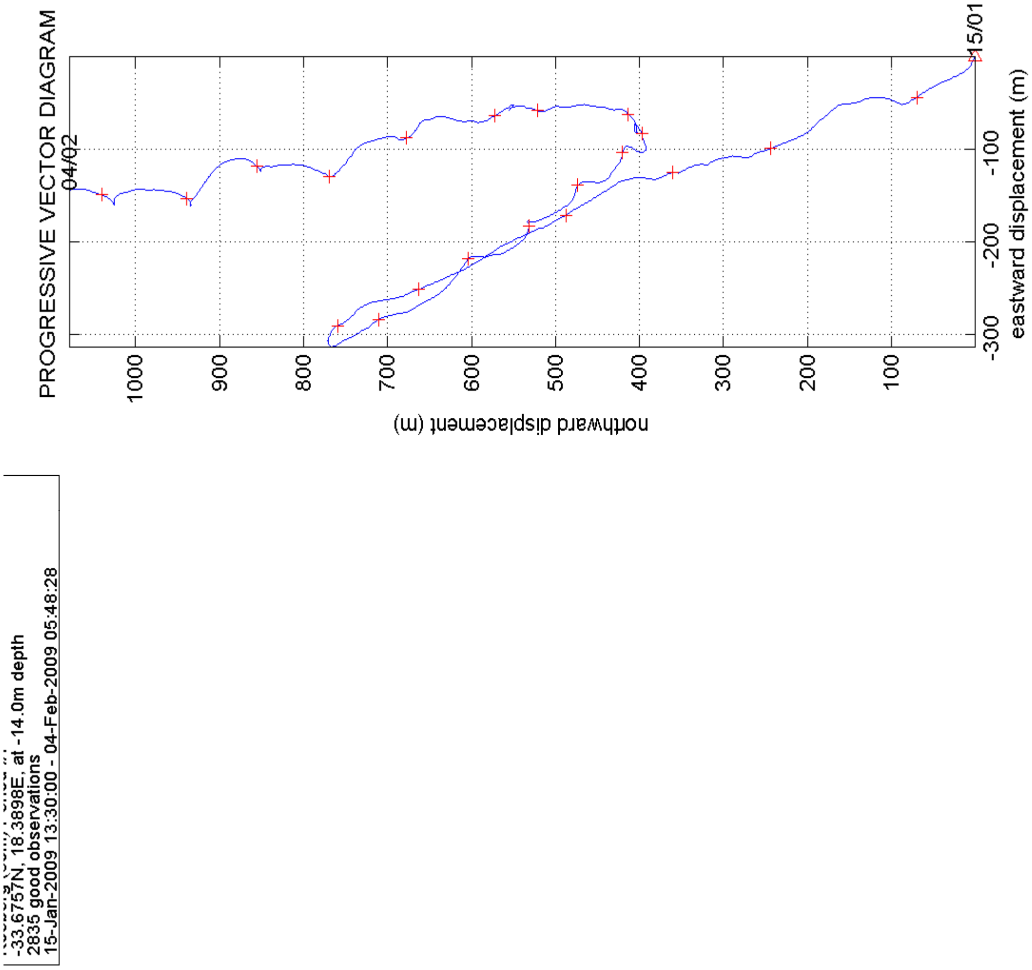


Figure 24: Progressive vector plot of current data at 14.0m.

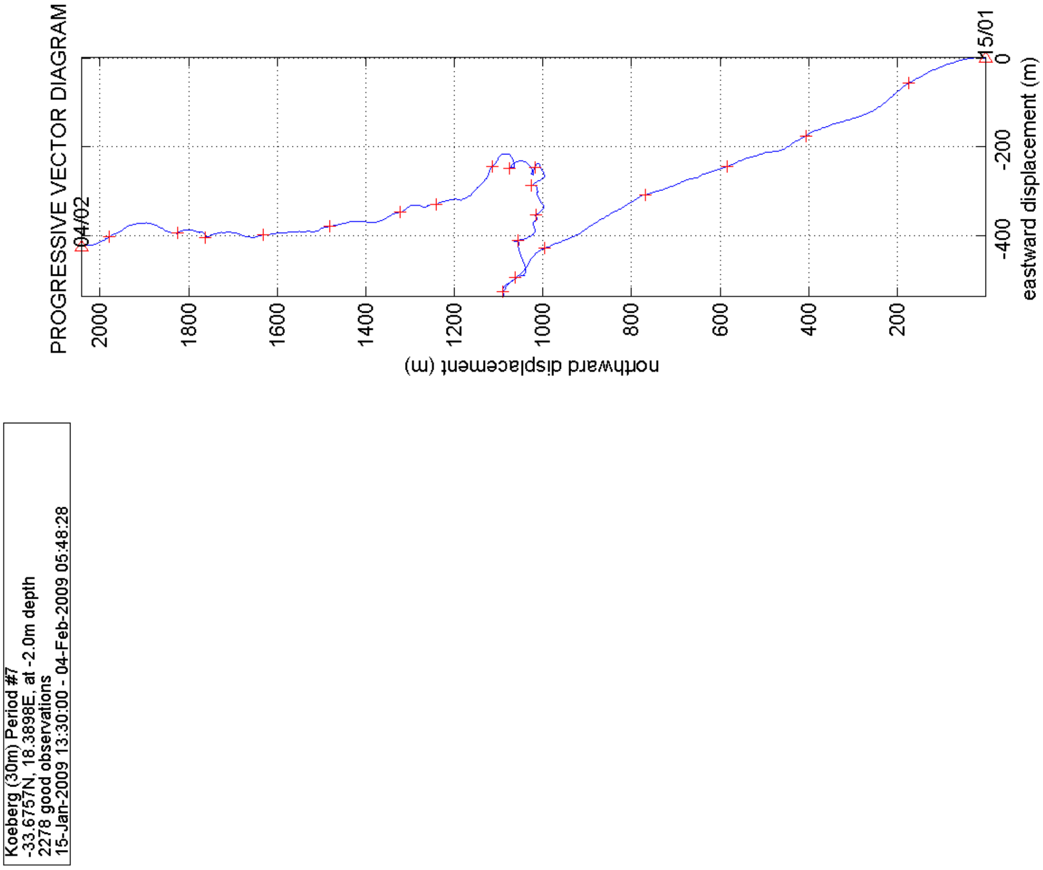


Figure 25: Progressive vector plot of current data at 2.0m.

5.2.2 Wave Data.

5.2.2.1 Hs and Tp summary plot

Figure 26 displays a summary plot for the wave parameters significant wave height (Hs) and peak period (Tp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Tp. Columns of the table represent Tp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Tp sector.
- The lower left hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.

5.2.2.2 Hs and Dp summary plot

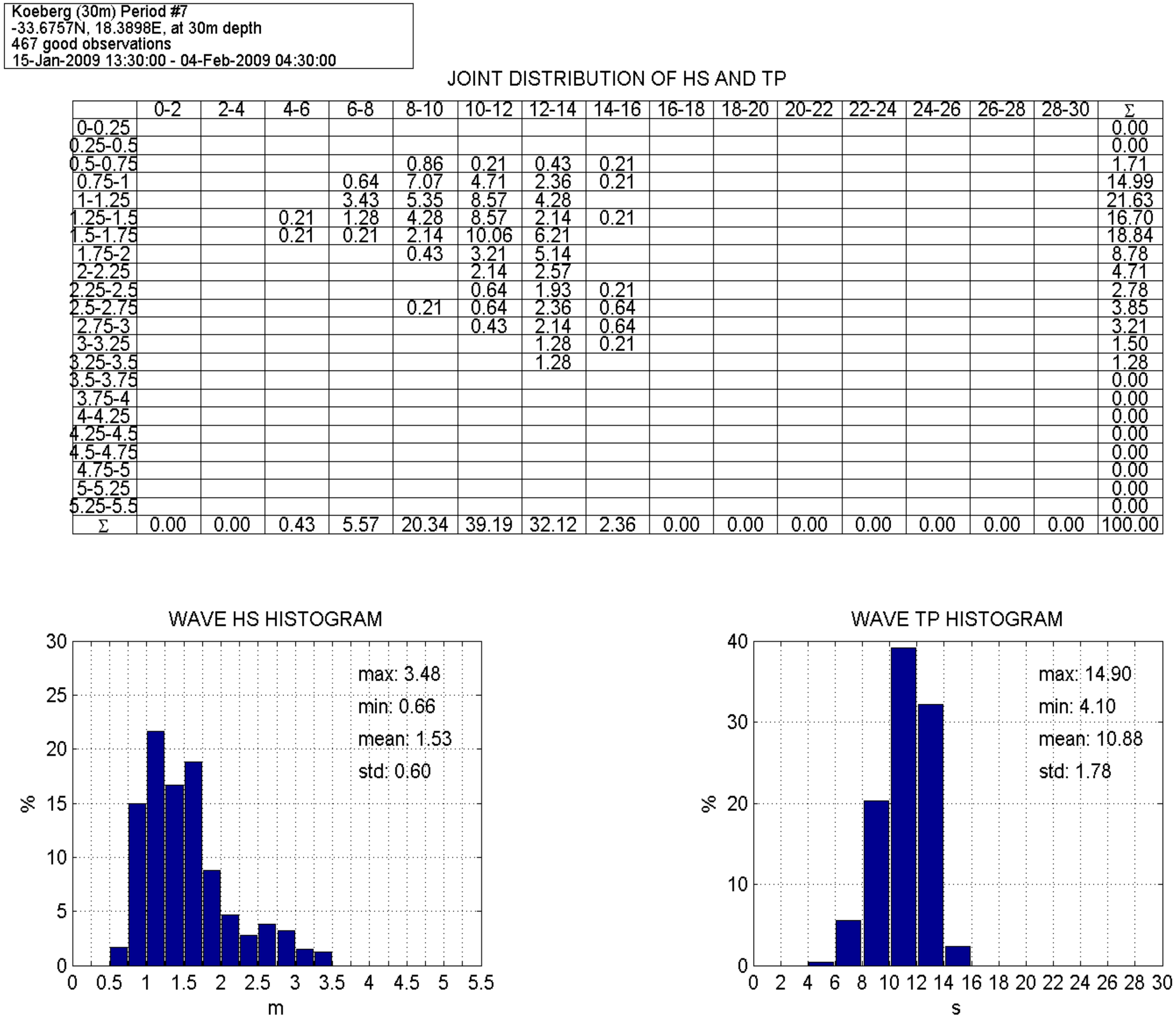
Figure 27 displays a summary plot for the wave parameters significant wave height (Hs) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Hs against Dp. Columns of the table represent Dp classes and rows the Hs classes. The numbers in the table reflect the percentage of observations that fall within a particular Hs and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Hs. This reflects the percentage of observations that fall within each Hs interval. Included on the plot are basic statistics for the Hs distribution.

5.2.2.3 Tp and Dp summary plot

Figure 28 displays a summary plot for the wave parameters peak period (Tp) and peak direction (Dp). The plots consist of:

- The upper panel is a table of the joint distribution of Tp against Dp. Columns of the table represent Dp classes and rows the Tp classes. The numbers in the table reflect the percentage of observations that fall within a particular Tp and Dp sector.
- The lower left hand panel is a rose of the observed Dp. This is a histogram of the directional distribution and reflects the percentage of observations that fall within each direction sector.
- The lower right hand panel is a histogram of the observed Tp. This reflects the percentage of observations that fall within each Tp interval. Included on the plot are basic statistics for the Tp distribution.



Koeberg (30m) Period #7
-33.6757N, 18.3898E, at 30m depth
467 good observations
15-Jan-2009 13:30:00 - 04-Feb-2009 04:30:00

JOINT DISTRIBUTION OF HS AND TP

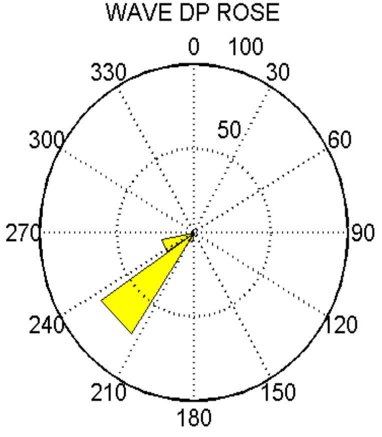
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	Σ
0-0.25																0.00
0.25-0.5																0.00
0.5-0.75					0.86	0.21	0.43	0.21								1.71
0.75-1				0.64	7.07	4.71	2.36	0.21								14.99
1-1.25				3.43	5.35	8.57	4.28									21.63
1.25-1.5			0.21	1.28	4.28	8.57	2.14	0.21								16.70
1.5-1.75			0.21	0.21	2.14	10.06	6.21									18.84
1.75-2					0.43	3.21	5.14									8.78
2-2.25						2.14	2.57									4.71
2.25-2.5						0.64	1.93	0.21								2.78
2.5-2.75					0.21	0.64	2.36	0.64								3.85
2.75-3						0.43	2.14	0.64								3.21
3-3.25							1.28	0.21								1.50
3.25-3.5							1.28									1.28
3.5-3.75																0.00
3.75-4																0.00
4-4.25																0.00
4.25-4.5																0.00
4.5-4.75																0.00
4.75-5																0.00
5-5.25																0.00
5.25-5.5																0.00
Σ	0.00	0.00	0.43	5.57	20.34	39.19	32.12	2.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Figure 26: Summary plot of H_s and T_p.

Koeberg (30m) Period #7
-33.6757N, 18.3898E, at 30m depth
467 good observations
15-Jan-2009 13:30:00 - 04-Feb-2009 04:30:00

JOINT DISTRIBUTION OF HS AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-0.25																	0.00
0.25-0.5																	0.00
0.5-0.75											1.28	0.43					1.71
0.75-1										1.93	10.71	2.14	0.21				14.99
1-1.25									0.21	1.28	14.56	5.35	0.21				21.63
1.25-1.5									0.21	1.07	13.06	2.36					16.70
1.5-1.75										1.28	14.99	2.36			0.21		18.84
1.75-2											7.28	1.50					8.78
2-2.25											3.64	1.07					4.71
2.25-2.5										0.21	1.28	1.28					2.78
2.5-2.75										0.21	2.57	1.07					3.85
2.75-3											1.50	1.71					3.21
3-3.25											0.43	1.07					1.50
3.25-3.5											0.86	0.43					1.28
3.5-3.75																	0.00
3.75-4																	0.00
4-4.25																	0.00
4.25-4.5																	0.00
4.5-4.75																	0.00
4.75-5																	0.00
5-5.25																	0.00
5.25-5.5																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	6.00	72.16	20.77	0.43	0.00	0.21	0.00	100.00



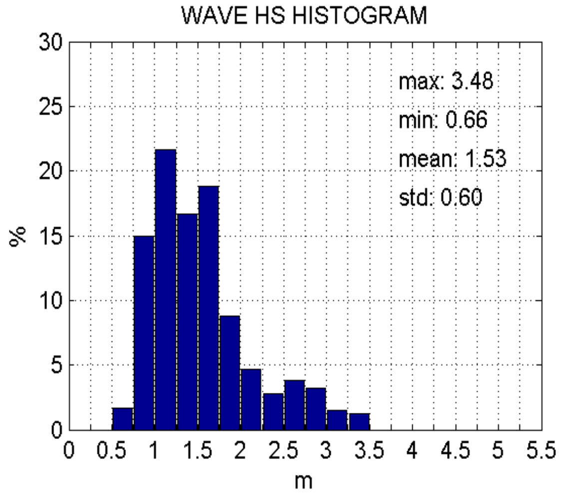
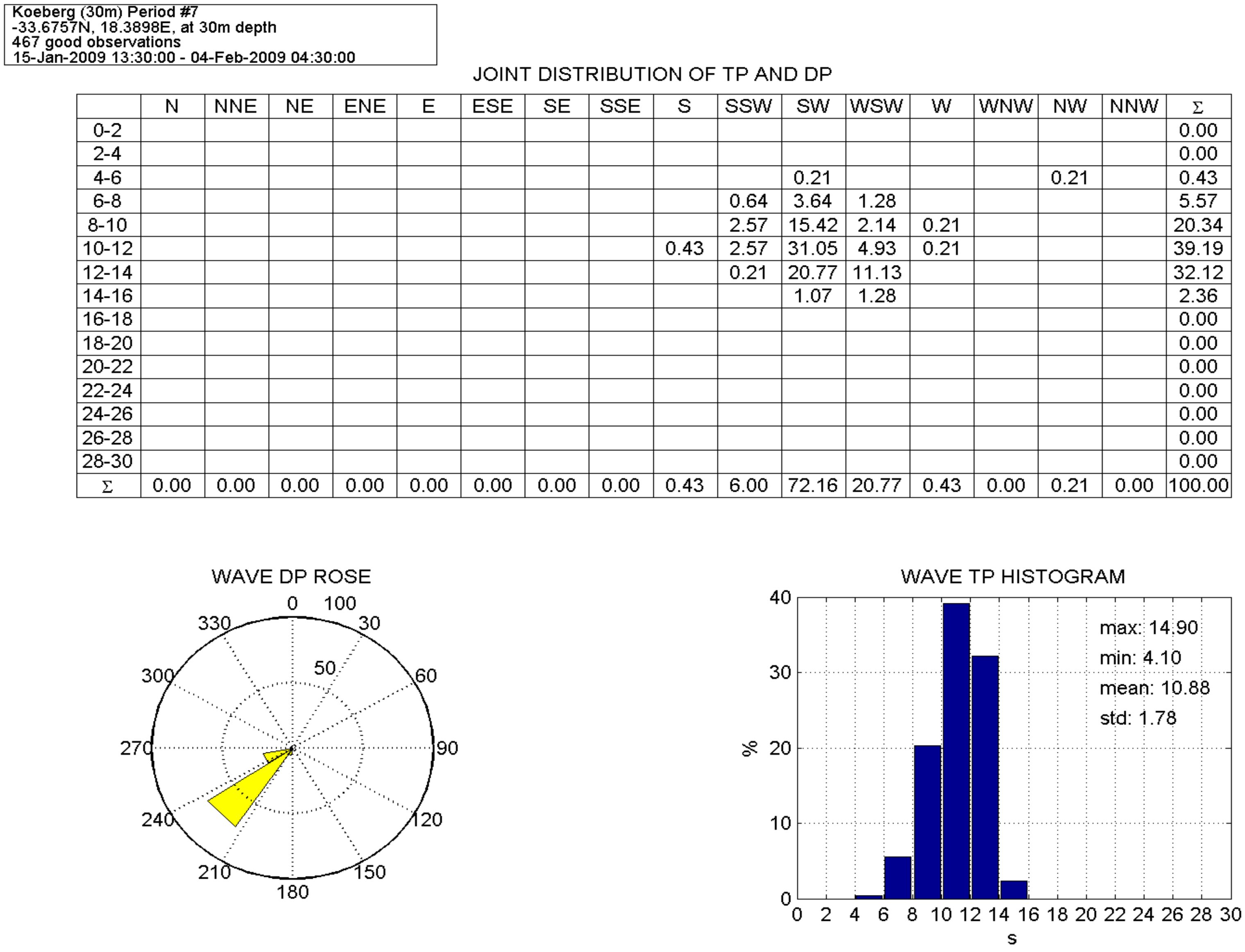


Figure 27: Summary plot of H_s and D_p.



Koeberg (30m) Period #7
-33.6757N, 18.3898E, at 30m depth
467 good observations
15-Jan-2009 13:30:00 - 04-Feb-2009 04:30:00

JOINT DISTRIBUTION OF TP AND DP

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ
0-2																	0.00
2-4																	0.00
4-6											0.21				0.21		0.43
6-8										0.64	3.64	1.28					5.57
8-10										2.57	15.42	2.14	0.21				20.34
10-12									0.43	2.57	31.05	4.93	0.21				39.19
12-14										0.21	20.77	11.13					32.12
14-16											1.07	1.28					2.36
16-18																	0.00
18-20																	0.00
20-22																	0.00
22-24																	0.00
24-26																	0.00
26-28																	0.00
28-30																	0.00
Σ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	6.00	72.16	20.77	0.43	0.00	0.21	0.00	100.00

Figure 28: Summary plot of T_p and D_p.

5.2.2.4 Wave spectral plot

Figure 29 displays wave spectral plots for a significant wave event. The time of each spectra is given in the title of the graph. The plots consist of:

- The spectral energy for each frequency is presented on the left panel.
- The direction spectrum for each frequency is presented on the right panel.

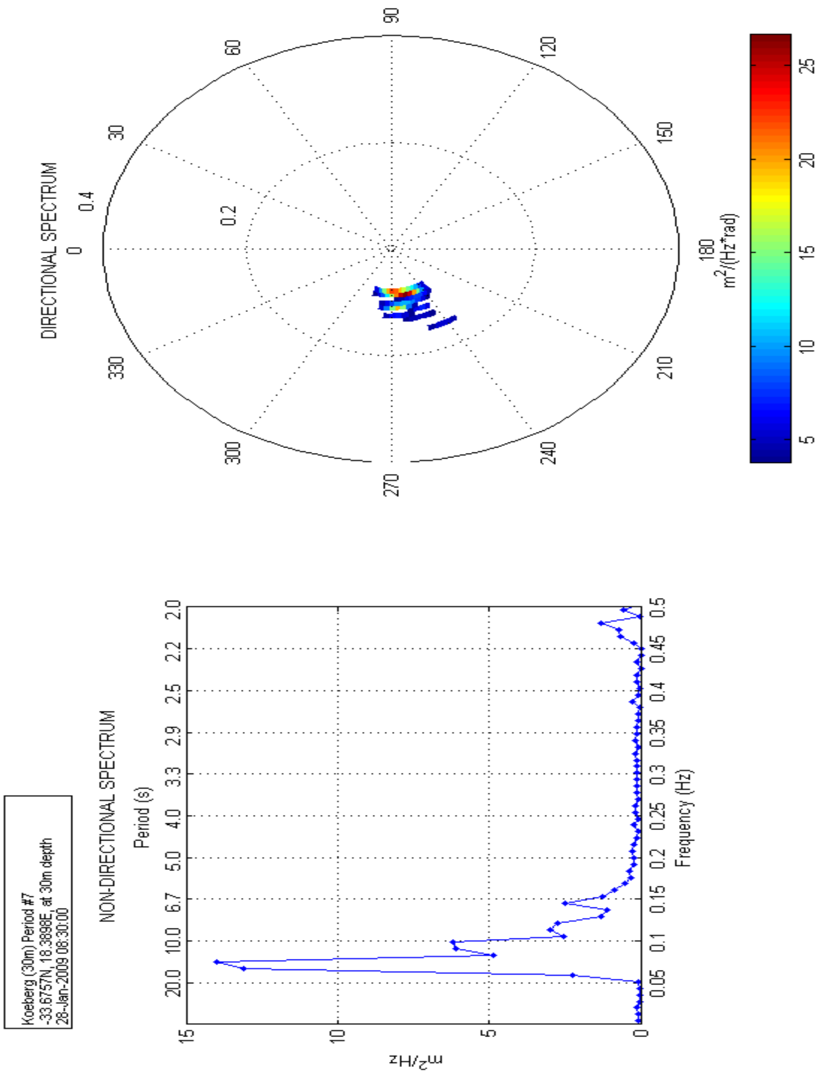


Figure 29: Wave spectra for 28th January 2009 at 08:30:00.

5.3 COMPARISON PLOTS

5.3.1 Hs, Tp and Dp time series plots for 10m and 30m ADCPs.

Figure 30 displays a time series plot of the main wave parameters:

- The first (upper) panel is of the significant wave height (Hs).
- The second panel is of the peak period (Tp).
- The third panel is of the peak wave direction (Dp).

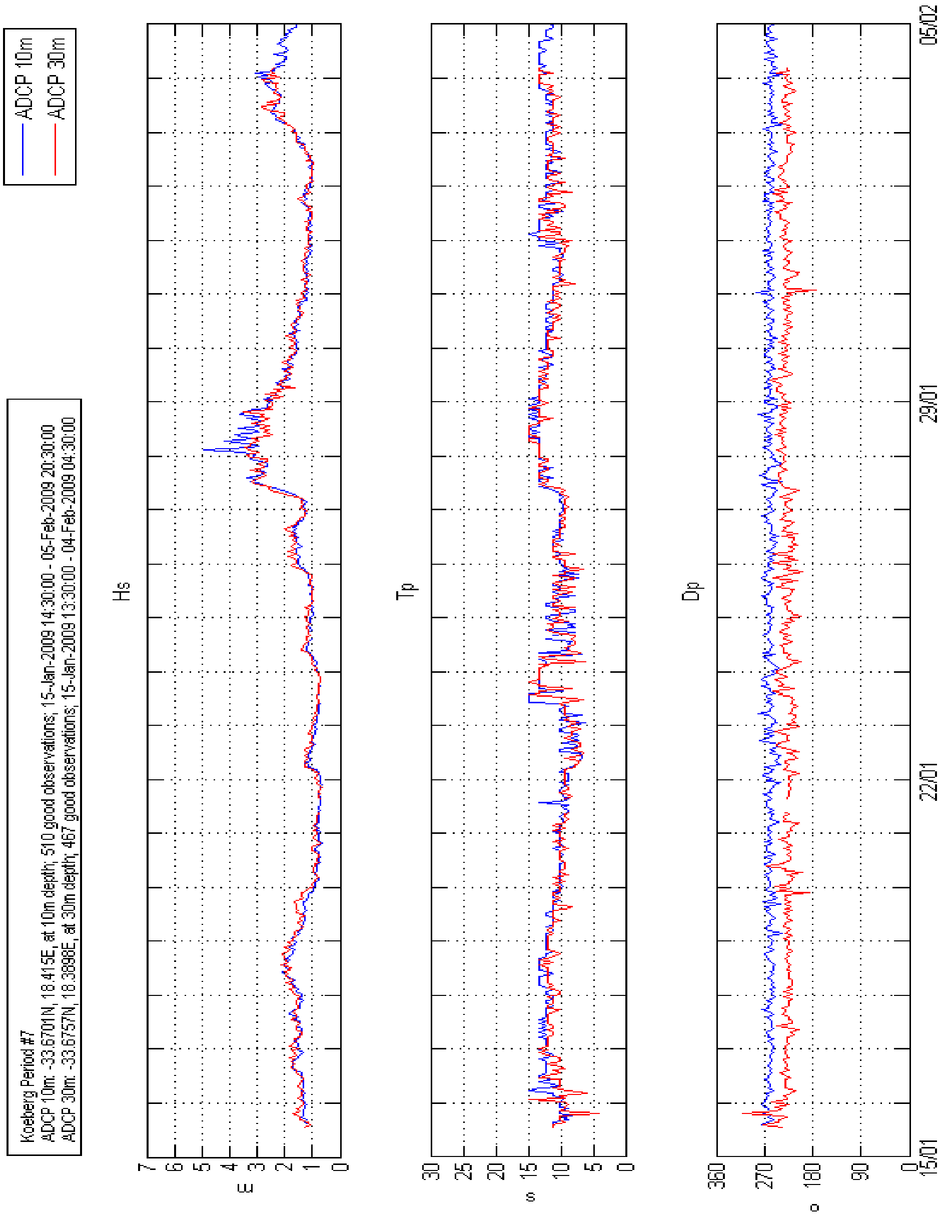


Figure 30: Wave Hs, Tp, and Dp for 10m and 30m ADCP.

5.3.2 Water properties: RBR-CT loggers, Thermister String and ADCPs temperature sensors.

Figure 31 displays a time series plot, which consists of:

- The first panel is of the observed water temperature from surface and bottom RBR loggers, as well as ADCP temperature sensor against time.
- The second panel is of the derived salinity from the two RBR loggers against time.

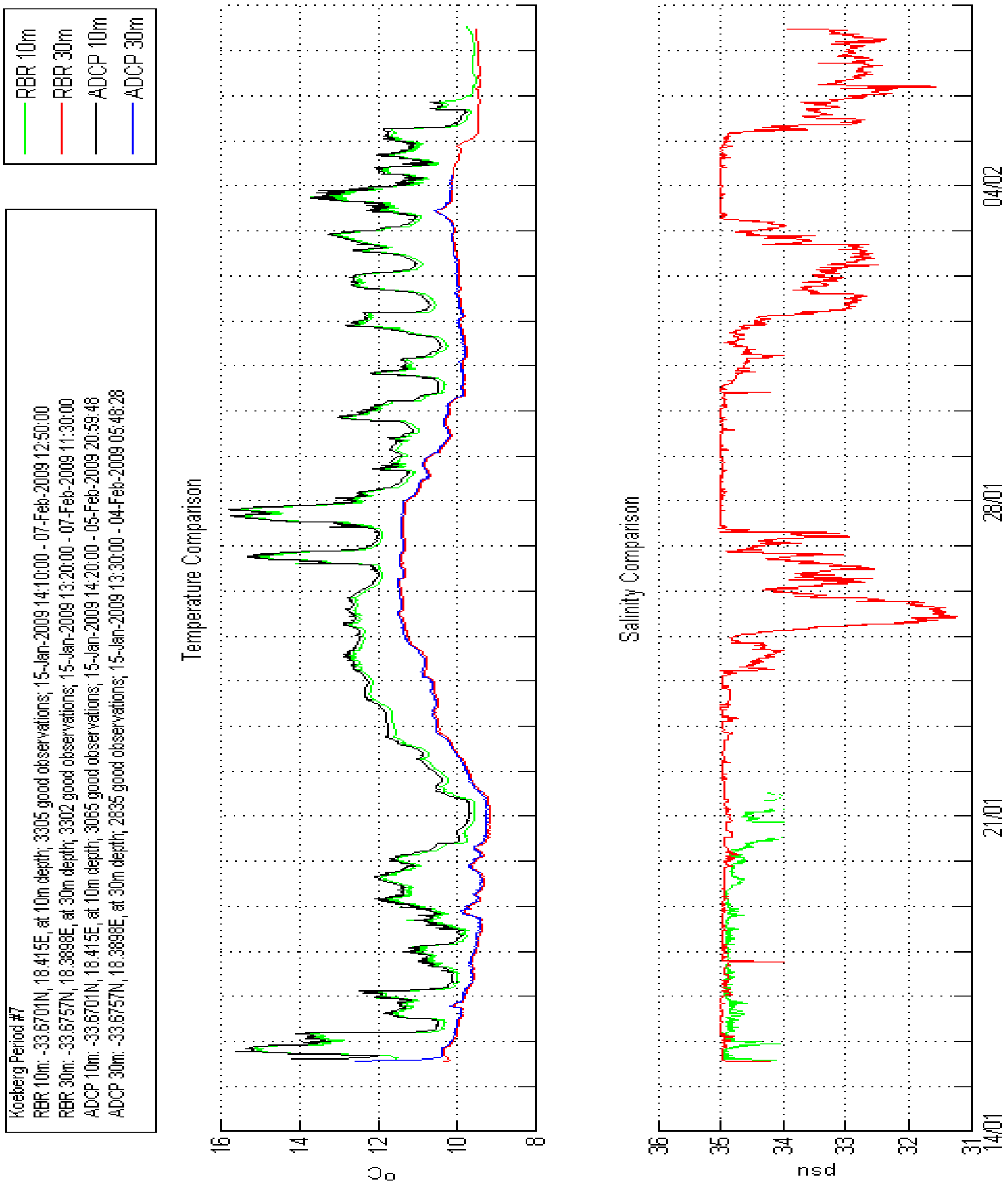


Figure 31: Time series of temperature and salinity from the RBR logger and ADCPs.

6. DISCUSSION

The sixth set of oceanographic data collected at Koeberg for the period between December 6th 2008 and January 11th 2009 has been presented in this report. The measurements taken fall within a larger dataset being compiled to assist a preliminary safety survey of multiple sites around the South African coast reports for Eskom.

At the Koeberg site, 2 600 kHz ADCPs and 2 RBR-CT loggers have been deployed to measure currents, waves and water temperature and salinity. The ADCPs are fixed on a frame at ~10m and ~30m. The RBR loggers are attached to the frame.

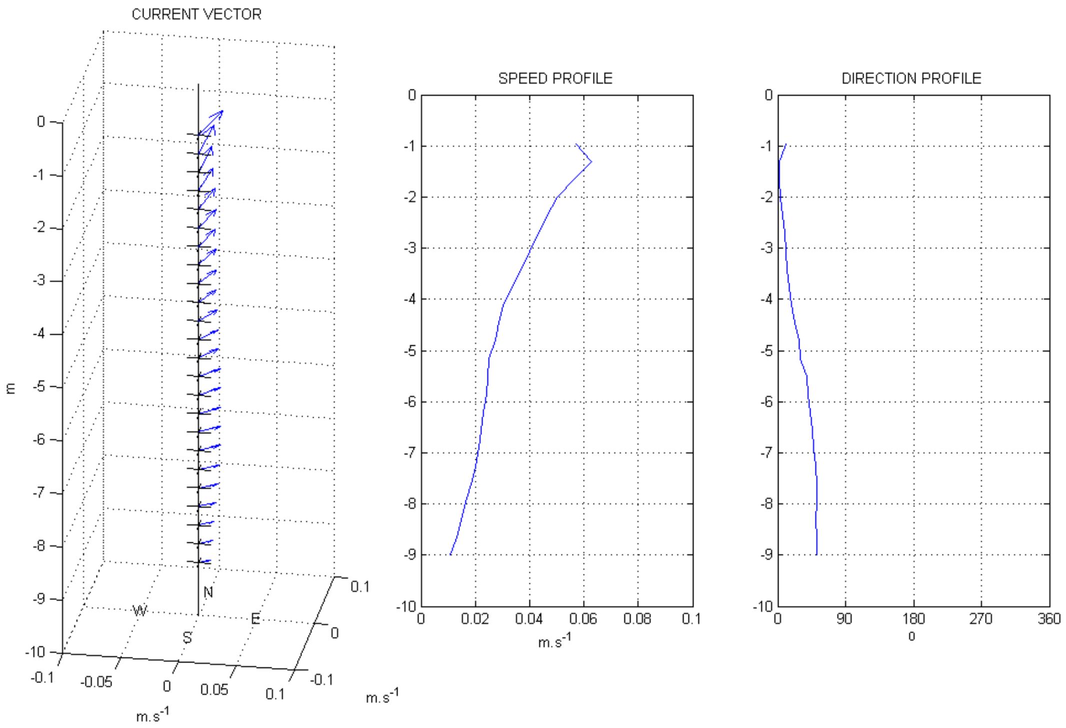


Figure 32: Mean profile plot for 10m ADCP.

The average surface current speed at the 10m site was ~0.18ms^{-1}, decreasing to ~0.09ms^{-1} at ~9m depth. The flow throughout the water column was variable. The mean current profile plot, presented in Figure 32, shows the gradual decrease in the vector mean speed.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.51m, with a wave period of 12.15s and mean direction to W/WSW.

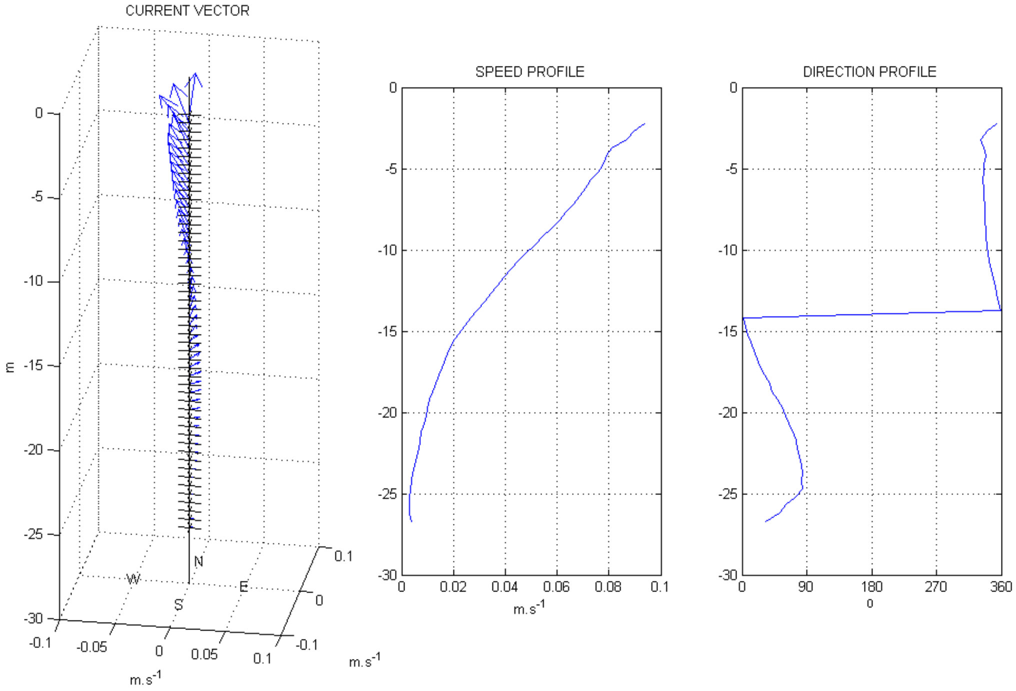


Figure 33: Mean profile plot for 30m ADCP.

The average current speed at the 30m site was ~0.19ms^{-1} at ~2m depth, decreasing to ~0.05ms^{-1} at ~27m depth. The flow throughout the water column was variable.

Wave measurements indicated that, over the period of time, the average significant wave height was 1.41m, with a wave period of 11.34s and mean direction to WSW/SW.

The temperature values recorded from the various independent instruments are in agreement with each other. However, salinity values from the RBR loggers are not consistent. Salinity values at the 10m Site drift possibly due to biofouling around the sensor.

7. INSTRUMENT PARTICULARS FOR SERVICE VISIT SIX

7.1 ADCP RECOVERY AND RE-DEPLOYMENT SHEETS

10m ADCP.

1. RECOVERY **Site Name: Koeberg 10m** **Date: 7 February 2009**

Instrument type and serial number			RDI	10841
Recovery date and time	LTx	GMT	**7 Feb 2009 12:30**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LTx	GMT	7 Feb 2009 19:17	
File size			205MB	
Was the data copied to memory card?			Y	N

2. **RE-DEPLOYMENT** **Site Name: Koeberg 10m** **Date : 8 February 2009**

Instrument type and serial number (do not ignore – if same, please indicate)			RDI	**10841**
Install a new battery and/or check the voltage				**1*44.9V**
Frequency of unit being used			**600KHz**	
Depth range			**10m**	
Number of bins (calculated automatically)			**42**	
Bin Size (calculated automatically)			**0.35**	
Wave burst duration			**40min**	
Time between wave bursts			**60min**	
Pings per ensemble			**500**	
Ensemble interval			**10min**	
Deployment duration			**13 days**	
Transducer depth			**10m**	
Any other commands			**RI0,minTP**	
Temperature			**5**	
Recorder size			**2 * 1GB**	

Consequences of the sampling parameters

First and last bin range			**1.41**	**15.76**
Battery usage				**476Wh**
Standard deviation				**1.08**
Storage space required				**113MB**
Set the ADCP clock	LT-x	GMT	**8 Feb 2009 07:56**	
Run pre-deployment tests				**Yes**
Name the ADCP deployment			**K1002**	

Deployment details

Switch on date and time	LTx	GMT	**8 Feb 2009 10:00:00**
Deployment date and time	LTx	GMT	**8 Feb 2009 16:15**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.198**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.896**

Site depth	10m	Deployment depth	**10m**
Acoustic release (1) serial number and release code			
Acoustic release (2) serial number and release code			
Argos beacon serial number		**-**	
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)		**K1013**	

3. **RECOVERY** **Site Name: Koeberg 10m** **Date: 7 February 2009**

Instrument type and serial number		XR 420	12995
Recovery date and time	LTx	GMT	**7 Feb 2009 12:30**
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**
Switch off date and time	LTx	GMT	7 Feb 2009 19:55
File size			74KB
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 7 February 2009/RBR_RecoveredData

30m ADCP.

1. RECOVERY **Site Name: Koeberg 30m** **Date: 11 Jan 2009.**

Instrument type and serial number		RDI	10119
Recovery date and time	LTx	GMT	**7 Feb 2009 11:15**
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Switch off date and time	LTx	GMT	8 Feb 2009 06:07
File size			159MB
Was the data copied to memory card?		Y	N

2. **RE-DEPLOYMENT** **Site Name: Koeberg 30m** **Date: 8 Feb 2009 .**

Instrument type and serial number (do not ignore – if same, please indicate)	RDI	**10119**
Install a new battery and/or check the voltage		**1*44.6V**
Frequency of unit being used	**600KHz**	
Depth range	**30m**	
Number of bins (calculated automatically)	**69**	
Bin Size (calculated automatically)	**0.5**	
Wave burst duration	**40min**	
Time between wave bursts	**60min**	
Pings per ensemble	**250**	
Ensemble interval	**10min**	
Deployment duration	**13 days**	
Transducer depth	**30m**	
Any other commands	**RI0,minTP**	

Temperature	**5**
Recorder size	**1128MB**

Consequences of the sampling parameters

First and last bin range		**1.6**	**35.6**
Battery usage			**435Wh**
Standard deviation			**0. 86**
Storage space required			**114MB**
Set the ADCP clock	LT-x	GMT	**8 Feb 2009 07:09**
Run pre-deployment tests			**Yes**
Name the ADCP deployment			**K3002**

Deployment details

Switch on date and time	LT-x	GMT	**8 Feb 2009 10:00:00**
Deployment date and time	LT-x	GMT	**8 Feb 2009 13:20**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Site depth	30m	Deployment depth	**29.6**
Acoustic release (1) serial number and release code			
Acoustic release (2) serial number and release code			
Argos beacon serial number			
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**K3002**

3. RECOVERY Site Name: Koeberg 30m Date: 11 Jan 2009

Instrument type and serial number		RDI	10119
Recovery date and time	LTx	GMT	11 Jan 2009 08:15
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Switch off date and time	LTx	GMT	11 Jan 2009 11:52
File size			158MB
Was the data copied to memory card?		Yx	N

4. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 15 Jan 2009 .

Instrument type and serial number (do not ignore – if same, please indicate)	RDI	**10119**
Install a new battery and/or check the voltage		**1*44.9V**
Frequency of unit being used		**600KHz**
Depth range		**30m**
Number of bins (calculated automatically)		**69**
Bin Size (calculated automatically)		**0.5**
Wave burst duration		**34.16min**
Time between wave bursts		**60min**
Pings per ensemble		**250**
Ensemble interval		**10min**
Deployment duration		**15 days**
Transducer depth		**30m**
Any other commands		**RI0,minTP**

Temperature	**5**
Recorder size	**1128MB**

Consequences of the sampling parameters

First and last bin range		**1.6**	**35.6**
Battery usage			**449Wh**
Standard deviation			**0. 86**
Storage space required			**112MB**
Set the ADCP clock	LT-x	GMT	**11 Jan 2009 09:52:00**
Run pre-deployment tests			**Yes**
Name the ADCP deployment			**K3001**

Deployment details

Switch on date and time	LT-x	GMT	**11 Jan 2009 11:30:00**
Deployment date and time	LT-x	GMT	**15 Jan 2009 13:40:00**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Site depth	30m	Deployment depth	**30m**
Acoustic release (1) serial number and release code			**32385**
Acoustic release (2) serial number and release code			
Argos beacon serial number			
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**K3001**

7.2 RBR-CT LOGGERS RECOVERY AND RE-DEPLOYMENT SHEETS

10m Logger.

1. RECOVERY Site Name: Koeberg 10m Date: 7 Feb 2009

Instrument type and serial number		XR 420	12995
Recovery date and time	LTx	GMT	**7 Feb 2009 12:30**
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**
Switch off date and time	LT	GMT	7 Feb 2009 19:55
File size			74KB
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 7 February 2009/RBR_RecoveredData

2. RE-DEPLOYMENT Site Name: Koeberg 10m Date: 8 Feb 2009

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12995
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period		**10 min**
Averaging period		**1 min**
Expected deployment duration		**3 weeks**
Start of logging (date / time)	8 Feb 2009	10:00:00
End of logging (date / time)	20 Mar 2009	12h00
Memory usage		.4%
Battery usage		999mAH

Deployment details

Deployment date and time	LT	GMT	8 Feb 2009 16:15
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.198**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.896**
Site name			Koeberg 10m
Site depth			10m
Deployment depth			9.6m
Acoustic release (1) serial number and release code			**-**
Acoustic release (2) serial number and release code			**-**
Argos beacon serial number			**-**
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 8 February 2009/RBR_RecoveredData/**012995**

30m Logger.

1. RECOVERY Site Name: Koeberg 30m Date: 7 February 2009

Instrument type and serial number			XR 420	12997
Recovery date and time	LT	GMT	**7 Feb 2009 11:15**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.397**	
Switch off date and time	LT	GMT	7 Feb 2009 19:58	
File size			74KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 7 February 2009/RBR_RecoveredData	

2. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 8 Feb 2009

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12997
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	8 Feb 2009	10:00:00
End of logging (date / time)	20 March 2009	12h00
Memory usage		.4%
Battery usage		999mAH

Deployment details

Deployment date and time	LT - x	GMT	8 Feb 2009 13:20	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.397**	
Site name			Koeberg 30m	
Site depth			30m	
Deployment depth			29.6m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 7 February 2009/RBR_RecoveredData/**012997.log**	

7.3 ADCP CONFIGURATION FILES

10m ADCP.

```
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4800
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
TF09/02/08 10:00:00
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 312.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 2000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 113.20 MB (118698528 bytes)
;Power usage         = 376.92 Wh
;Battery usage       = 0.8
;Samples / Wv Burst = 4800
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
```

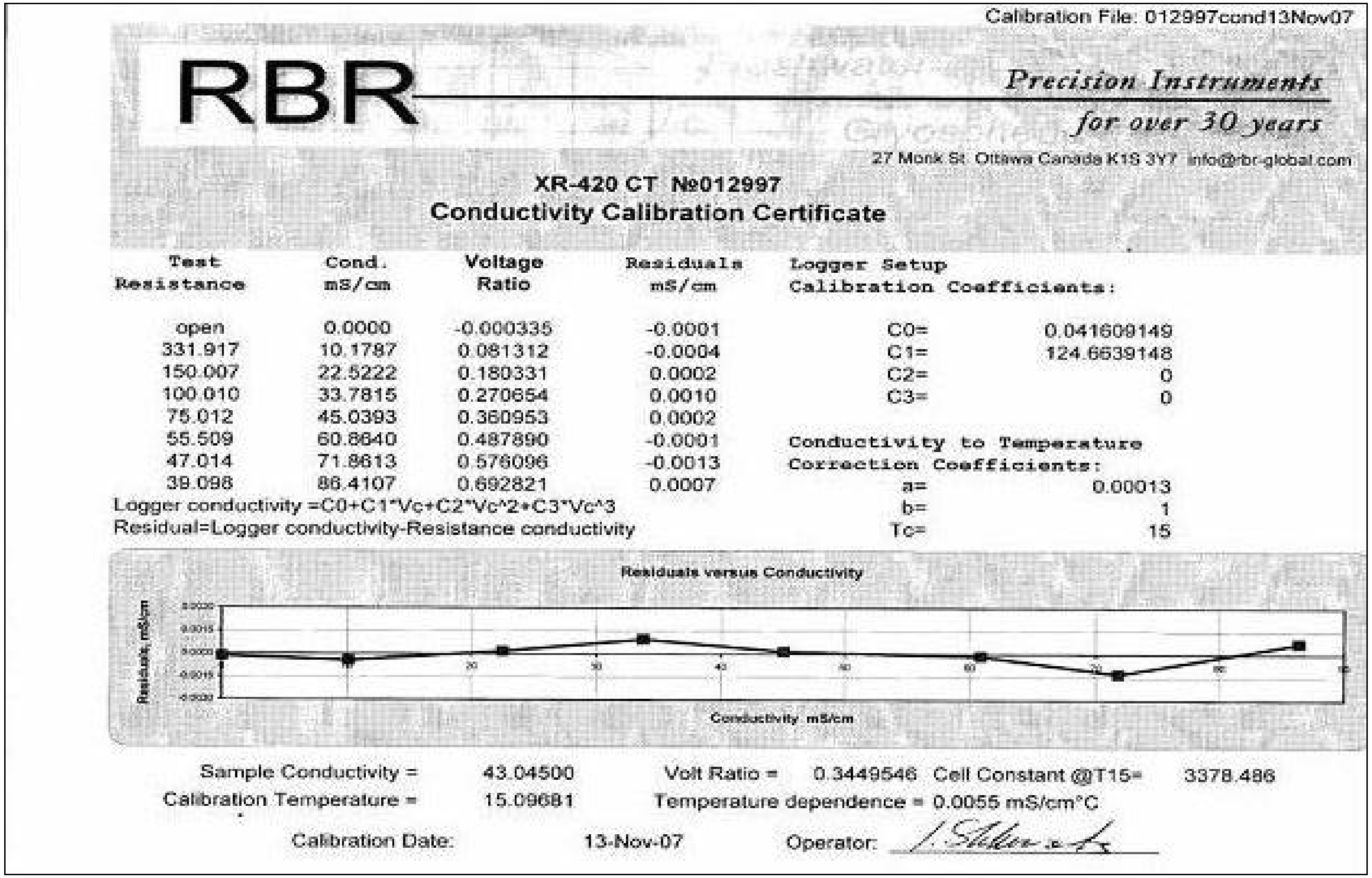
```
;Bytes / Wave Burst = 374480
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

30m ADCP.

```
CR1
CF11101
EA0
EB0
ED300
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN69
WP250
WS50
WV175
HD111000000
HB5
HP4800
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
TF09/02/08 10:00:00
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 312.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1128
;Saved Screen        = 3
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.60 m
```

```
;Last cell range    = 35.60 m
;Max range          = 38.22 m
;Standard deviation = 0.86 cm/s
;Ensemble size      = 1534 bytes
;Storage required   = 114.16 MB (119709408 bytes)
;Power usage        = 435.03 Wh
;Battery usage      = 1.0
;Samples / Wv Burst = 4800
;Min NonDir Wave Per= 2.59 s
;Min Dir Wave Period= 4.31 s
;Bytes / Wave Burst = 374480
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

7.4 RBR-CT CALIBRATION CERTIFICATES



Calibration File: 012997cond13Nov07

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012997
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000335	-0.0001
331.917	10.1787	0.081312	-0.0004
150.007	22.5222	0.180331	0.0002
100.010	33.7815	0.270654	0.0010
75.012	45.0393	0.360953	0.0002
55.509	60.8640	0.487890	-0.0001
47.014	71.8613	0.576096	-0.0013
39.098	86.4107	0.692821	0.0007

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

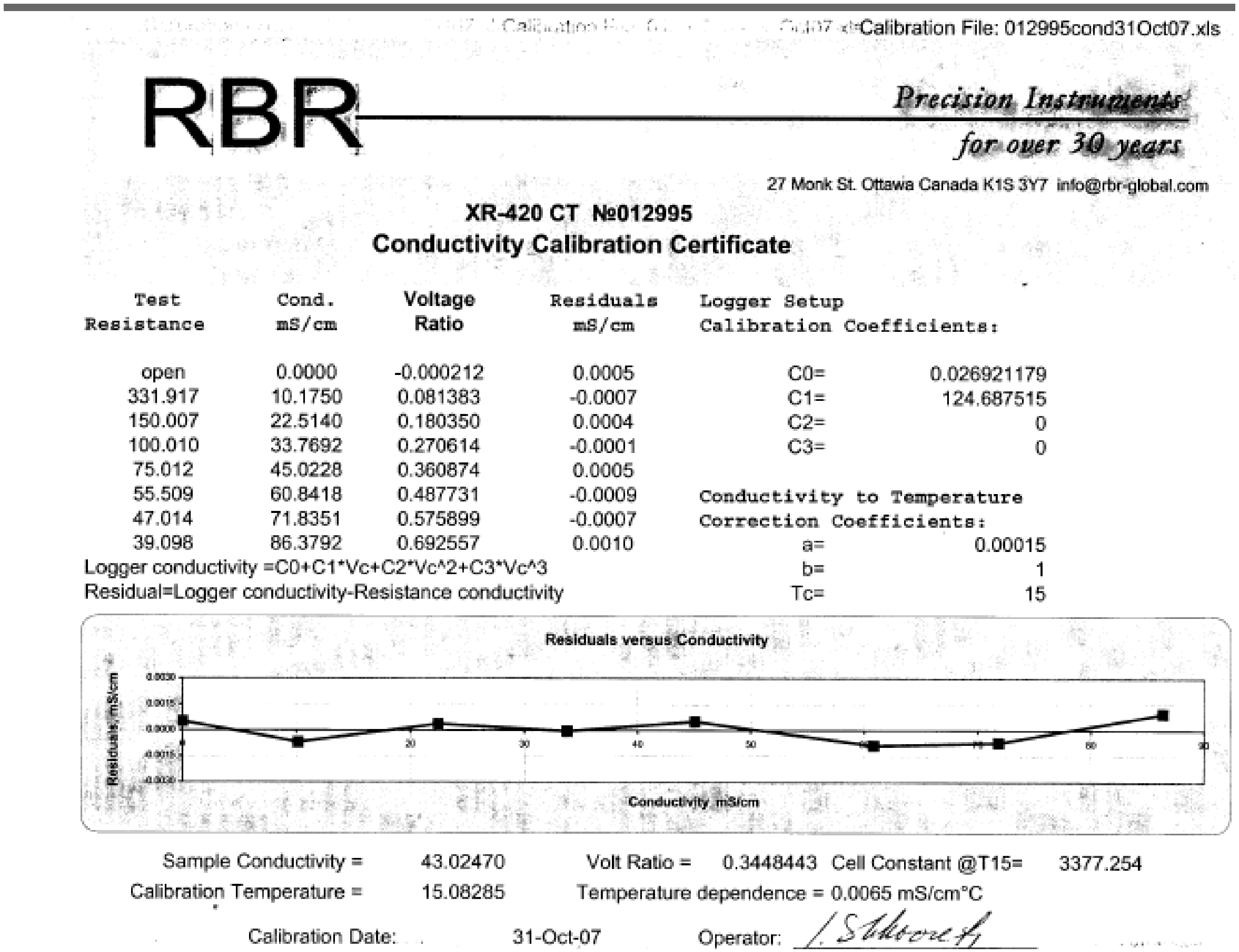
C0= 0.041609149
C1= 124.6639148
C2= 0
C3= 0

Conductivity to Temperature
Correction Coefficients:

a= 0.00013
b= 1
Tc= 15

Sample Conductivity = 43.04500
Calibration Temperature = 15.09681
Volt Ratio = 0.3449546
Cell Constant @T15= 3378.486
Temperature dependence = 0.0055 mS/cm°C

Calibration Date: 13-Nov-07
Operator: J. Stellen



Calibration File: 012995cond31Oct07.xls

RBR

Precision Instruments
for over 30 years

27 Monk St. Ottawa Canada K1S 3Y7 info@rbr-global.com

XR-420 CT №012995
Conductivity Calibration Certificate

Test Resistance	Cond. mS/cm	Voltage Ratio	Residuals mS/cm
open	0.0000	-0.000212	0.0005
331.917	10.1750	0.081383	-0.0007
150.007	22.5140	0.180350	0.0004
100.010	33.7692	0.270614	-0.0001
75.012	45.0228	0.360874	0.0005
55.509	60.8418	0.487731	-0.0009
47.014	71.8351	0.575899	-0.0007
39.098	86.3792	0.692557	0.0010

Logger conductivity =C0+C1*Vc+C2*Vc^2+C3*Vc^3
Residual=Logger conductivity-Resistance conductivity

Logger Setup
Calibration Coefficients:

C0= 0.026921179
C1= 124.687515
C2= 0
C3= 0

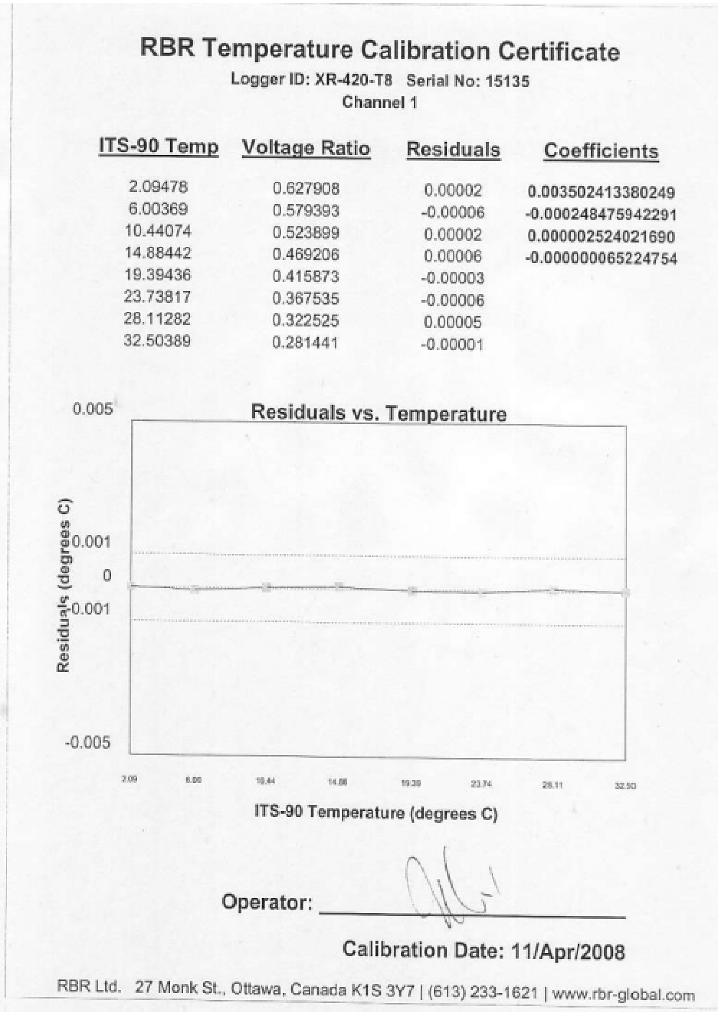
Conductivity to Temperature
Correction Coefficients:

a= 0.00015
b= 1
Tc= 15

Residuals versus Conductivity

Sample Conductivity = 43.02470
Volt Ratio = 0.3448443
Cell Constant @T15= 3377.254
Calibration Temperature = 15.08285
Temperature dependence = 0.0065 mS/cm°C

Calibration Date: 31-Oct-07
Operator:



RBR Temperature Calibration Certificate

Logger ID: XR-420-T8 Serial No: 15135
Channel 1

ITS-90 Temp	Voltage Ratio	Residuals	Coefficients
2.09478	0.627908	0.00002	**0.003502413380249**
6.00369	0.579393	-0.00006	**-0.000248475942291**
10.44074	0.523899	0.00002	**0.000002524021690**
14.88442	0.469206	0.00006	**-0.000000065224754**
19.39436	0.415873	-0.00003	
23.73817	0.367535	-0.00006	
28.11282	0.322525	0.00005	
32.50389	0.281441	-0.00001	

Residuals vs. Temperature

Operator: ______________________

Calibration Date: 11/Apr/2008

RBR Ltd. 27 Monk St., Ottawa, Canada K1S 3Y7 | (613) 233-1621 | www.rbr-global.com

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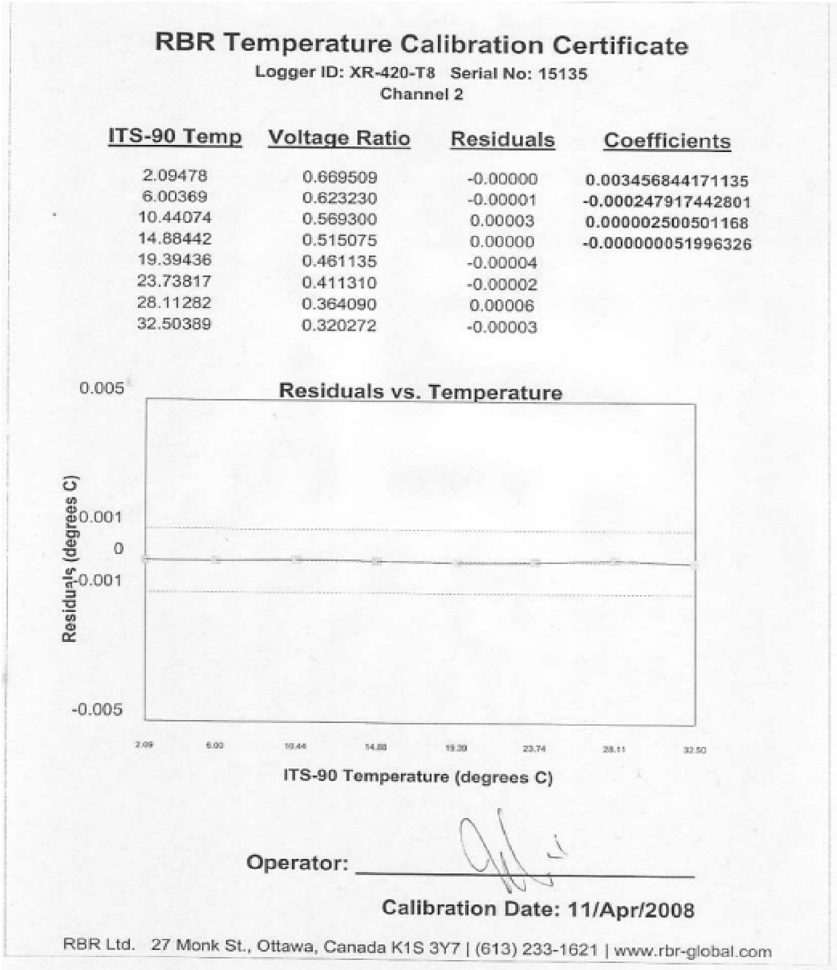


RBR Temperature Calibration Certificate

Logger ID: XR-420-T8 Serial No: 15135
Channel 2

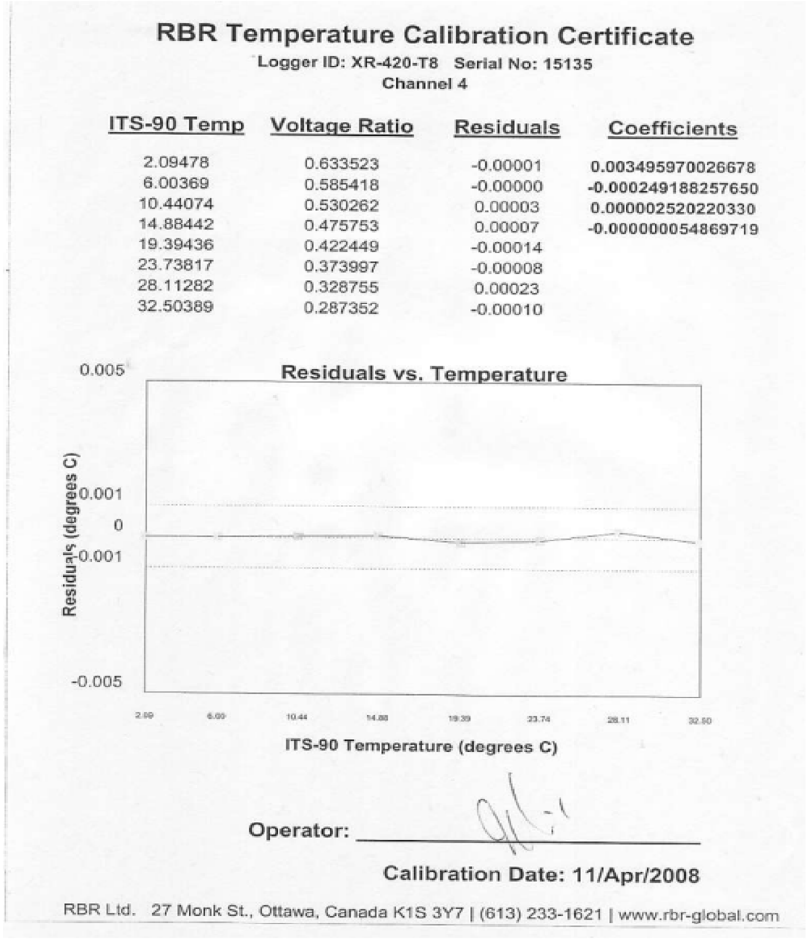
ITS-90 Temp	Voltage Ratio	Residuals	Coefficients
2.09478	0.669509	-0.00000	**0.003456844171135**
6.00369	0.623230	-0.00001	**-0.000247917442801**
10.44074	0.569300	0.00003	**0.000002500501168**
14.88442	0.515075	0.00000	**-0.000000051996326**
19.39436	0.461135	-0.00004	
23.73817	0.411310	-0.00002	
28.11282	0.364090	0.00006	
32.50389	0.320272	-0.00003	

Residuals vs. Temperature

Operator: ______________________

Calibration Date: 11/Apr/2008

RBR Ltd. 27 Monk St., Ottawa, Canada K1S 3Y7 | (613) 233-1621 | www.rbr-global.com



RBR Temperature Calibration Certificate

Logger ID: XR-420-T8 Serial No: 15135
Channel 4

ITS-90 Temp	Voltage Ratio	Residuals	Coefficients
2.09478	0.633523	-0.00001	0.003495970026678
6.00369	0.585418	-0.00000	-0.000249188257650
10.44074	0.530262	0.00003	0.000002520220330
14.88442	0.475753	0.00007	-0.000000054869719
19.39436	0.422449	-0.00014	
23.73817	0.373997	-0.00008	
28.11282	0.328755	0.00023	
32.50389	0.287352	-0.00010	

Operator: ______

Calibration Date: 11/Apr/2008

RBR Ltd. 27 Monk St., Ottawa, Canada K1S 3Y7 | (613) 233-1621 | www.rbr-global.com

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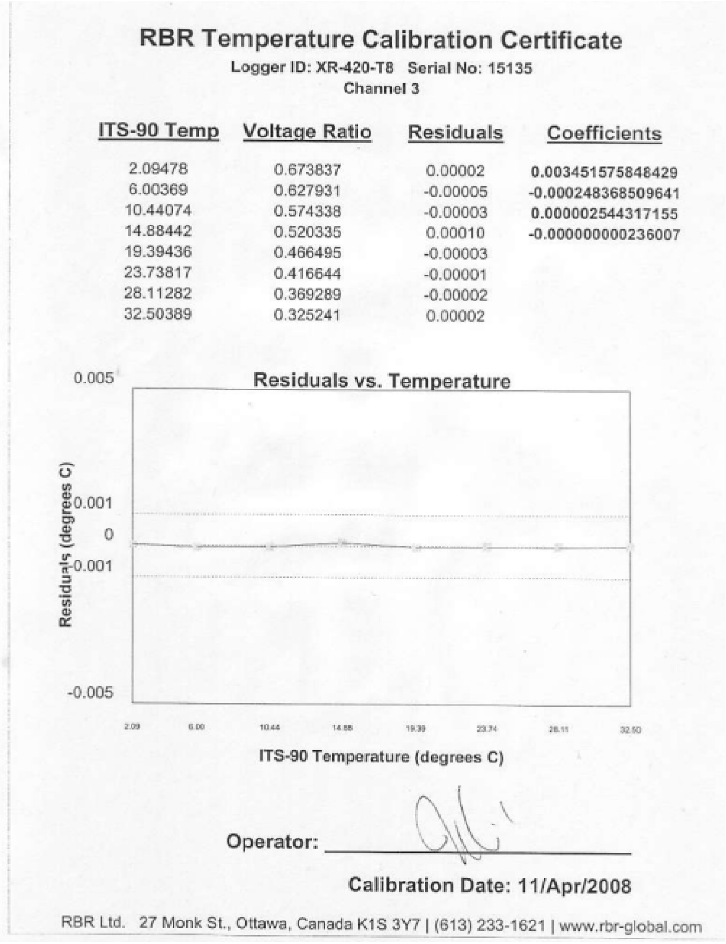


RBR Temperature Calibration Certificate

Logger ID: XR-420-T8 Serial No: 15135
Channel 3

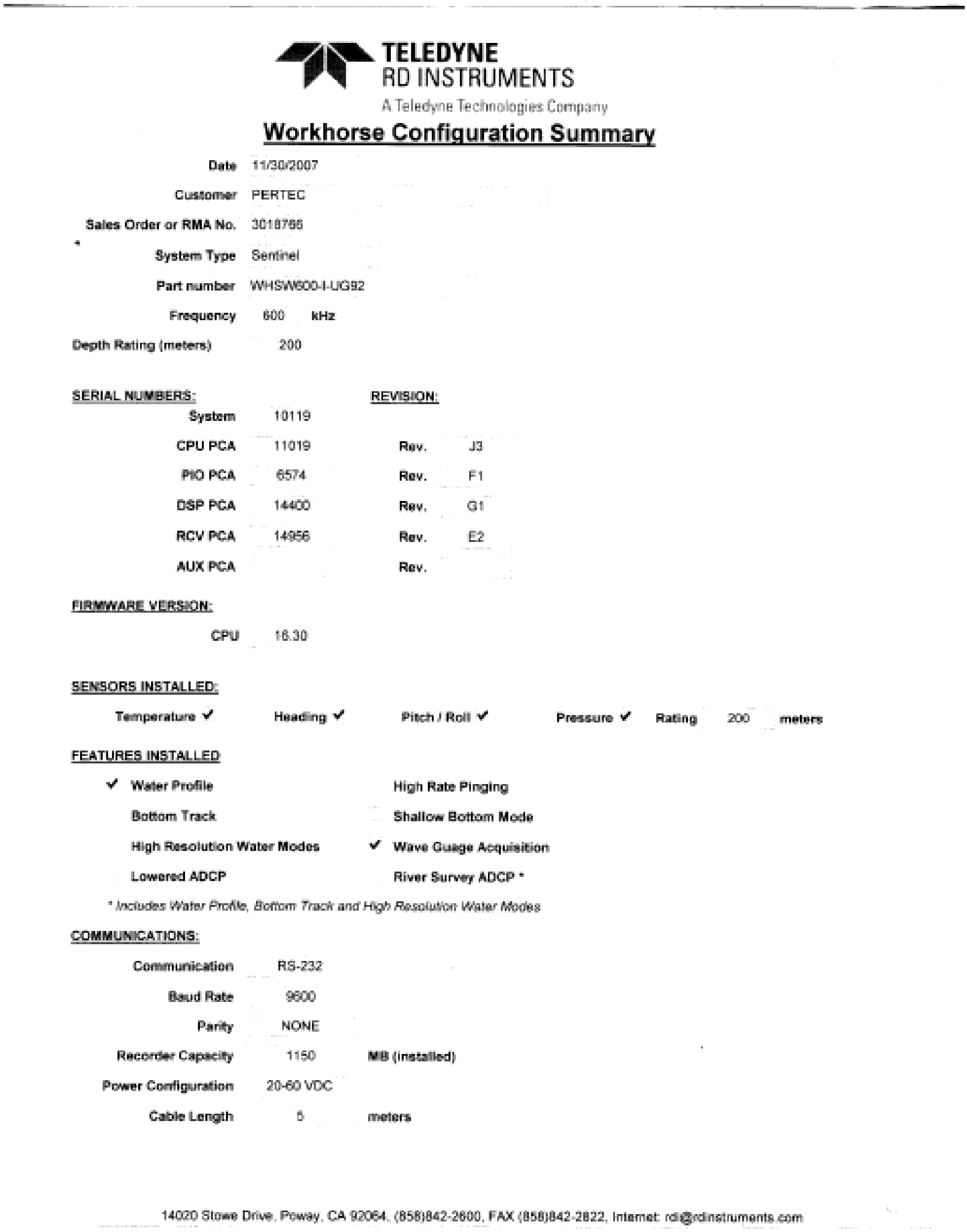
ITS-90 Temp	Voltage Ratio	Residuals	Coefficients
2.09478	0.673837	0.00002	0.003451575848429
6.00369	0.627931	-0.00005	-0.000248368509641
10.44074	0.574338	-0.00003	0.000002544317155
14.88442	0.520335	0.00010	-0.000000000236007
19.39436	0.466495	-0.00003	
23.73817	0.416644	-0.00001	
28.11282	0.369289	-0.00002	
32.50389	0.325241	0.00002	

Operator: ______

Calibration Date: 11/Apr/2008

RBR Ltd. 27 Monk St., Ottawa, Canada K1S 3Y7 | (613) 233-1621 | www.rbr-global.com

7.5 RDI ADCP CALIBRATION CERTIFICATE



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 11/30/2007

Customer PERTEC

Sales Order or RMA No. 3018766

System Type Sentinel

Part number WHSW600-I-UG92

Frequency 600 **kHz**

Depth Rating (meters) 200

SERIAL NUMBERS:		**REVISION:**	
System	10119		
CPU PCA	11019	**Rev.**	J3
PIO PCA	6574	**Rev.**	F1
DSP PCA	14400	**Rev.**	G1
RCV PCA	14956	**Rev.**	E2
AUX PCA		**Rev.**	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ✓ **Heading** ✓ **Pitch / Roll** ✓ **Pressure** ✓ **Rating** 200 **meters**

FEATURES INSTALLED

✓ **Water Profile**	**High Rate Pinging**
Bottom Track	**Shallow Bottom Mode**
High Resolution Water Modes	✓ **Wave Guage Acquisition**
Lowered ADCP	**River Survey ADCP** *

** Includes Water Profile, Bottom Track and High Resolution Water Modes*

COMMUNICATIONS:

Communication RS-232

Baud Rate 9600

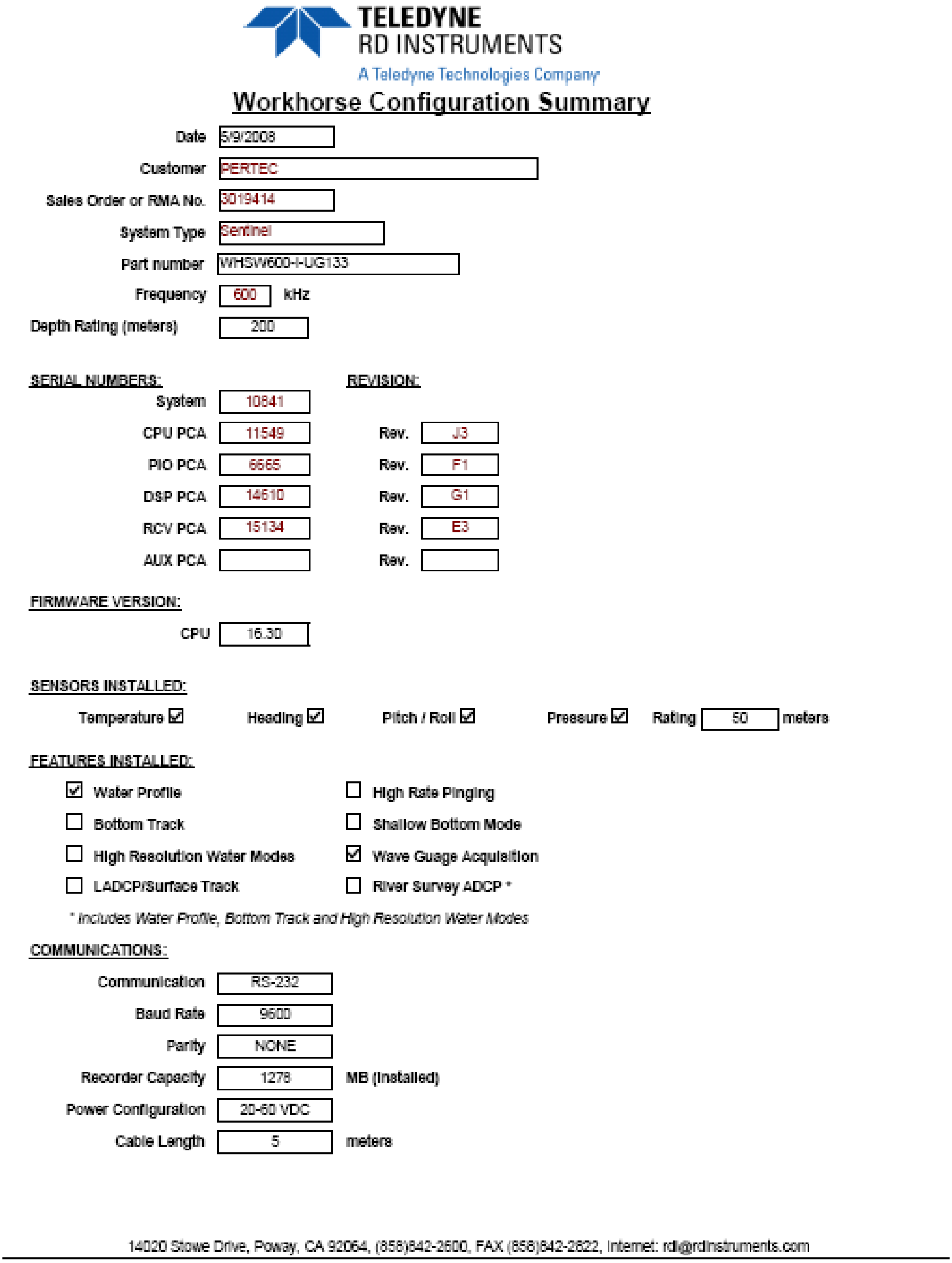
Parity NONE

Recorder Capacity 1150 **MB (installed)**

Power Configuration 20-60 VDC

Cable Length 5 **meters**

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2822, Internet: rdi@rdinstruments.com



TELEDYNE
RD INSTRUMENTS
A Teledyne Technologies Company

Workhorse Configuration Summary

Date 5/9/2008

Customer PERTEC

Sales Order or RMA No. 3019414

System Type Sentinel

Part number WHSW600-I-UG133

Frequency 600 kHz

Depth Rating (meters) 200

SERIAL NUMBERS:		REVISION:	
System	10841		
CPU PCA	11549	Rev.	J3
PIO PCA	6665	Rev.	F1
DSP PCA	14610	Rev.	G1
RCV PCA	15134	Rev.	E3
AUX PCA		Rev.	

FIRMWARE VERSION:

CPU 16.30

SENSORS INSTALLED:

Temperature ☑ Heading ☑ Pitch / Roll ☑ Pressure ☑ Rating 50 meters

FEATURES INSTALLED:

☑ Water Profile
☐ Bottom Track
☐ High Resolution Water Modes
☐ LADCP/Surface Track
☐ High Rate Pinging
☐ Shallow Bottom Mode
☑ Wave Guage Acquisition
☐ River Survey ADCP *

* Includes Water Profile, Bottom Track and High Resolution Water Modes

COMMUNICATIONS:

Communication RS-232

Baud Rate 9600

Parity NONE

Recorder Capacity 1278 MB (Installed)

Power Configuration 20-60 VDC

Cable Length 5 meters

14020 Stowe Drive, Poway, CA 92064, (858)842-2600, FAX (858)842-2622, Internet: rdi@rdinstruments.com

LWANDLE TECHNOLOGIES (PTY) LTD

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT EIGHT

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

28 August 2009

Job No: LT-JOB-50

Directors: C.P. Matthysen, M. Majodina, B.J. Spolander

LWANDLE TECHNOLOGIES (PTY) LTD
Unit 13/15 Constantia Business Park, Princess Vlei Road,
Diep River, 7800, South Africa

Co Reg. No. 2003/015524/07

TABLE OF CONTENTS

1. DISCLAIMER

The data is this report will undergo additional quality control procedures by Prestedge Retief Dresner Wijnberg (PRDW). For this reason no data in this report should be used for design purposes and only quality controlled data provided by PRDW should be used.

2. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 8 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary for 10m ADCP

Depth (m)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-8.4	0.6393	0.0736	0.0813	0.0236	18.49
-8.0	0.6366	0.0762	0.0841	0.0253	16.49
-7.7	0.6571	0.0785	0.0864	0.0267	15.30
-7.3	0.6544	0.0801	0.0886	0.0287	13.39
-7.0	0.6648	0.0818	0.0908	0.0306	10.08
-6.6	0.6907	0.0834	0.0931	0.0336	5.35
-6.3	0.7035	0.0851	0.0949	0.0361	1.65
-5.9	0.7359	0.0875	0.0966	0.0387	357.05
-5.6	0.7104	0.0899	0.0986	0.0418	353.64
-5.2	0.7041	0.0931	0.1005	0.0448	350.22
-4.9	0.7109	0.0960	0.1032	0.0488	346.75
-4.5	0.7200	0.0991	0.1046	0.0523	343.16
-4.2	0.7337	0.1029	0.1070	0.0572	339.88
-3.8	0.7102	0.1078	0.1088	0.0616	337.02
-3.5	0.7144	0.1124	0.1109	0.0671	334.88
-3.1	0.7213	0.1179	0.1121	0.0725	332.45
-2.8	0.7142	0.1241	0.1138	0.0777	330.99
-2.4	0.7067	0.1302	0.1159	0.0836	329.3
-2.1	0.7396	0.1369	0.118	0.0898	330.34
-1.7	0.7279	0.1509	0.1215	0.1009	338.02
-1.4	0.7521	0.1687	0.1258	0.1177	345.16
-1.0	0.8058	0.1817	0.1304	0.1268	352.02

Table 2 – Waves summary for 10m ADCP

	Max	Min	Mean	Std
Hs (m)	2.87	1.34	0.67	0.47
Tp (s)	17.00	11.63	4.60	1.67
Dp (°)	312.72	237.82	173.72	9.85

Table 3 – Current flow summary for 30m ADCP

Depth (m)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-26.7	0.2063	0.0492	0.0281	0.0066	51.34
-26.2	0.2008	0.0519	0.0290	0.0067	59.66
-25.7	0.2711	0.0544	0.0302	0.0072	65.87
-25.2	0.3821	0.0566	0.0314	0.0073	68.28
-24.7	0.5055	0.0585	0.0328	0.007	73.85
-24.2	0.6325	0.0604	0.0345	0.0072	78.87
-23.7	0.7327	0.062	0.0361	0.0075	78.67
-23.2	0.7790	0.0637	0.0372	0.0077	81.58
-22.7	0.8501	0.0652	0.0387	0.0075	79.62
-22.2	0.8470	0.0665	0.0395	0.0074	76.03
-21.7	0.8421	0.0682	0.0403	0.0076	72.89
-21.2	0.8170	0.0699	0.0414	0.0076	66.21
-20.7	0.8061	0.0716	0.0423	0.0073	58.19
-20.2	0.7726	0.0730	0.0432	0.0071	46.34
-19.7	0.7337	0.0744	0.0439	0.0075	34.92
-19.2	0.7225	0.0757	0.0447	0.0084	22.04
-18.7	0.7393	0.0767	0.0461	0.0101	8.81
-18.2	0.7087	0.0776	0.0469	0.0119	0.25
-17.7	0.7087	0.0789	0.0479	0.0141	352.07
-17.2	0.6725	0.0802	0.0491	0.0172	343.18
-16.7	0.6731	0.0817	0.0501	0.0203	338.82
-16.2	0.6862	0.0839	0.0518	0.0242	334.23
-15.7	0.6923	0.0863	0.0527	0.0276	332.72
-15.2	0.6930	0.0894	0.0540	0.0320	329.54
-14.7	0.6856	0.0920	0.0552	0.0348	329.03
-14.2	0.6573	0.0951	0.0565	0.0379	327.93
-13.7	0.6492	0.0979	0.0579	0.0409	326.96
-13.2	0.6470	0.1002	0.0599	0.044	325.77
-12.7	0.6520	0.1029	0.0616	0.0473	324.15
-12.2	0.6520	0.1054	0.0633	0.0506	322.87
-11.7	0.6506	0.1083	0.0650	0.0534	321.19
-11.2	0.6522	0.1109	0.0663	0.0563	319.76
-10.7	0.6713	0.1138	0.0680	0.0589	318.26
-10.2	0.6875	0.1170	0.0699	0.0616	316.68
-9.7	0.6738	0.1201	0.0716	0.0649	315.04
-9.2	0.6598	0.1231	0.0732	0.0679	313.63
-8.7	0.5736	0.1258	0.0749	0.0712	312.9
-8.2	0.5830	0.1281	0.0765	0.0749	311.81
-7.7	0.5601	0.1309	0.0788	0.0783	310.88
-7.2	0.5195	0.133	0.0811	0.0817	309.94
-6.7	0.4857	0.1353	0.0838	0.0858	309.29

-6.2	0.4627	0.1378	0.0858	0.0895	308.54
-5.7	0.4576	0.1412	0.0876	0.0936	308.33
-5.2	0.4439	0.1451	0.0889	0.0974	308.05
-4.7	0.4534	0.1489	0.0900	0.1019	308.00
-4.2	0.4629	0.1526	0.0914	0.1060	308.38
-3.7	0.4679	0.1563	0.0929	0.1097	309.65
-3.2	0.4873	0.1575	0.0927	0.1088	313.66
-2.7	0.4739	0.1611	0.0921	0.1084	324.53
-2.2	0.4626	0.1691	0.0898	0.1141	336.85

Table 4 – Waves summary for 30m ADCP

	Max	Min	Mean	Std
Hs (m)	2.92	0.66	1.39	0.54
Tp (s)	15.00	5.90	11.58	1.56
Dp (^{o})	257.72	187.72	221.05	9.13

Table 5 – Water temperature and salinity summary for 10m RBR logger

Parameter	Mean	Max	Min
Temperature (^{o}C)	11.04	14.37	9.65
Conductivity	37.96	41.54	29.31
Salinity (psu)	33.88	34.75	30.16

Table 6 – Water temperature and salinity summary for 30m RBR logger

Parameter	Mean	Max	Min
Temperature (^{o}C)	9.95	10.62	9.54
Conductivity	37.80	38.48	35.70
Salinity (psu)	34.74	34.96	32.09

2.1 DATA RETURN FOR KOEBERG SITE.

Table 7 – Data Return (%).

Koeberg P08	16 January 2008 / 11 July 2008 – 15 January 2009	15 January 2009 – 20 March 2009	8 February 2009 – 20 March 2009
Btm RBR Salinity	67	100	100
Surf RBR Salinity	48	72	100
10m ADCP Current	55	68	54
10m ADCP Wave	55	68	54
30m ADCP Current	57	60	44
30m ADCP Wave	56	60	44
Thermistor String	15	63	100
Temp-Btm RBR	68	100	100
Temp-Surf RBR	49	100	100
Temp-10m ADCP	55	68	54
Temp-30m ADCP	57	60	44
30m Temperature	77	100	100
10m Temperature	79	100	100

3. INTRODUCTION

3.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period February 8th 2009 – March 20th 2009. Service of the instruments was undertaken on April 3rd 2009.

3.2 MEASUREMENT LOCATION

Table 8 – Initial deployment locations.

Instrument	Latitude (°S)	Longitude (°E)
10m ADCP and RBR logger.	33.6701	18.4149
30m ADCP and RBR logger and	33.6757	18.3898
Thermistor string	33.6759	18.3097

Table 9 – Water Samples taken on April 3rd 2009.

Bottle #	STN #	Lat	Long	Exact Time HH:MM:SS	COMMENTS (if RBR profile is taken etc..)
1	30m	33 40.540	18 23.387	08:11	Depth: 4m
2	30m	33 40.540	18 23.387	08:14	Depth: 12m
3	30m	33 40.540	18 23.387	08:16	Depth: 20m
4	30m	33 40.540	18 23.387	08:20	Depth: 28m
5	10m	33 40.207	18 24.894	10:10	Depth: 4m
6	10m	33 40.207	18 24.894	10:13	Depth: 8m
7	1	33 40.511	18 25.381	10:27	Depth: 4m
8	2	33 40.447	18 25.403	10:25	Depth: 4m
9	3	33 40.325	18 25.010	10:23	Depth: 4m
10	4	33 40.344	18 25.389	10:21	Depth: 4m
11	5	33 40.332	18 25.335	10:19	Depth: 4m

4. OPERATIONS

4.1 SUMMARY OF EVENTS

Service of all instruments was undertaken on April 3rd 2009. Retrieval of biofouling plates was scheduled for this service. Water samples were taken.

4.2 INSTRUMENT CONFIGURATIONS

Configurations were as per specifications.

Note: Biofouling plates have been installed on frame to avoid third party interference (as of May 2009).

5. DATA QUALITY CONTROL

5.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

5.1.1 Current processing

- The record was truncated to exclude times pre and post deployment.
- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 17 W (both ADCP sites).
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP's pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of $0.2ms^{-1}$ was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined.
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

5.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 17' W (both ADCP sites).
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

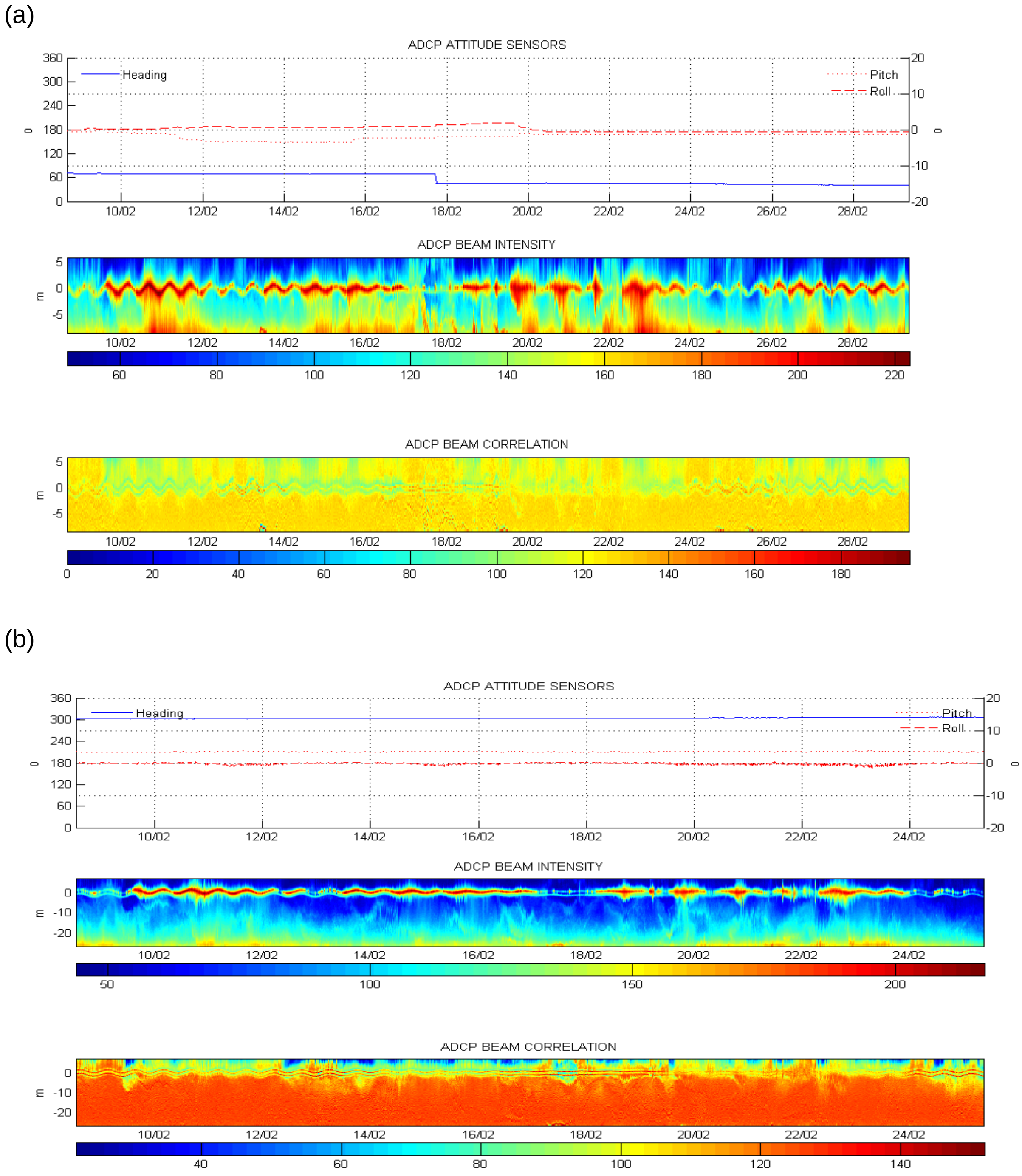


Figure 1: Quality control data from the (a) 10m and (b) 30m ADCPs. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

5.2 RBR-CT LOGGER AND THERMISTER STRING

The conductivity (from the CT-logger) and temperature data were exported directly from the RBR software into Matlab for further processing.

- The record was truncated to exclude times pre and post deployment.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.

5.3 BIOFOULING.

The following standard procedure is normally followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates is measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 $CaCO_3$ chips are added.
- Sample bottles are stored upright in the dark.

Biofouling plates were scheduled to be retrieved.

5.4 WATER SAMPLE.

Water samples were taken and sent to CSIR for analysis.

6. DATA PRESENTATION AND DISCUSSION

Biofouling plates: The divers had difficulty locating the biofouling plates that were not in their original location. After almost an hour's search, the divers were unsuccessful in locating the plates and the search was aborted.

The thermistor string was successfully deployed but due to its proximity to the surface we suspect it was tampered with and some nodes were damaged. Since redeployment the unit has returned data. We need to reconfigure the unit with new calibration coefficients (factory recalibration) to improve on the accuracy of the results from some of the nodes. This will happen in December 2009. The data presented here is therefore uncalibrated.

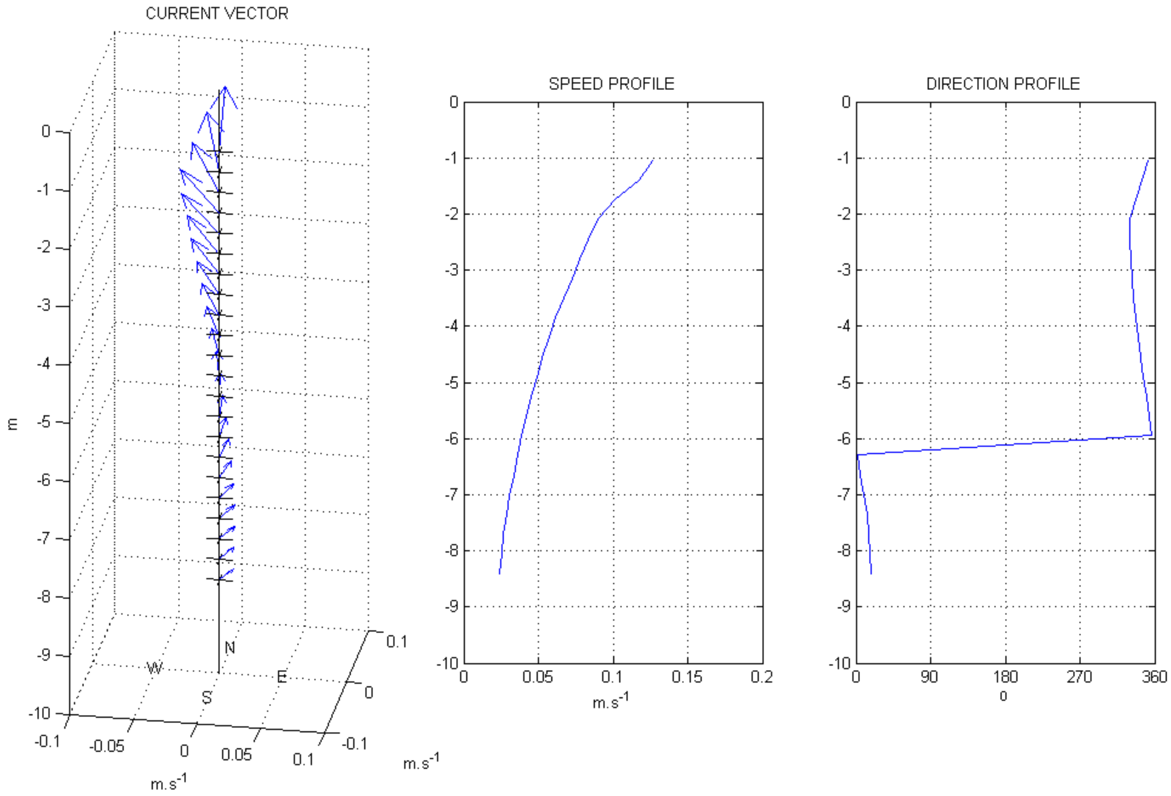


Figure 2: Mean profile plot for 10m ADCP.

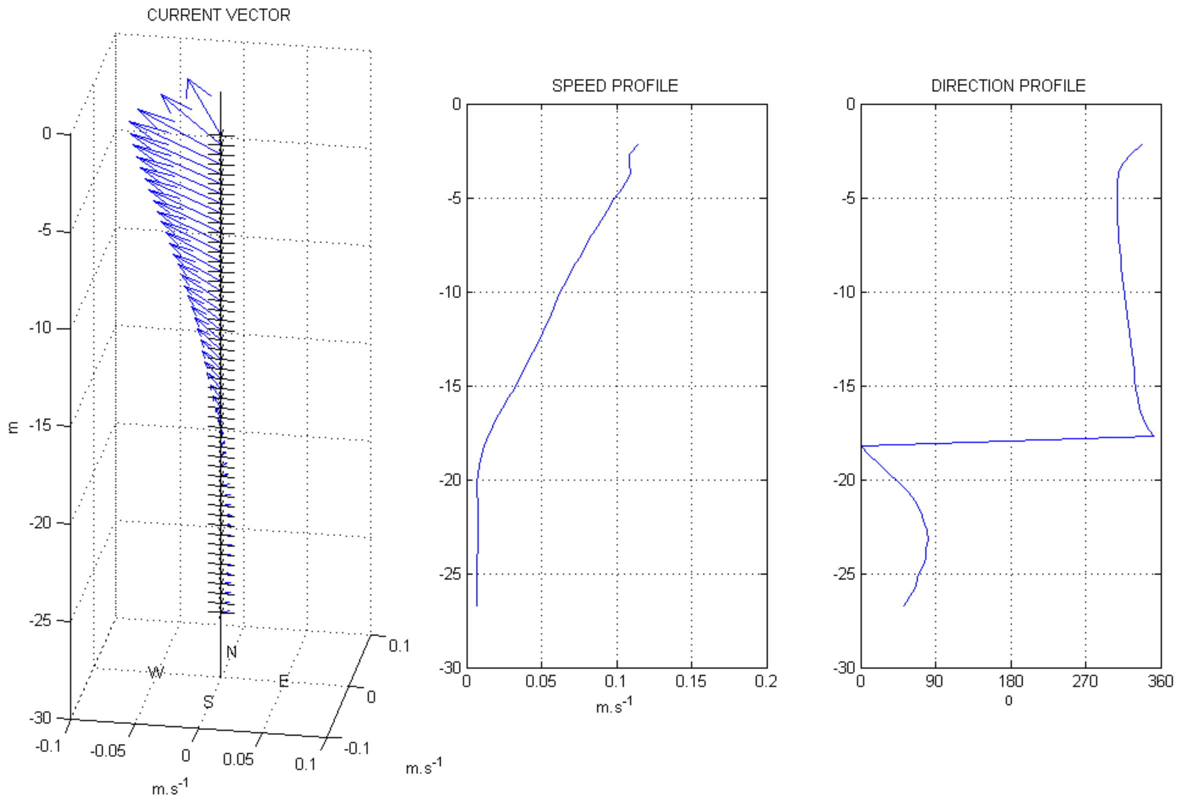


Figure 3: Mean profile plot for 30m ADCP.

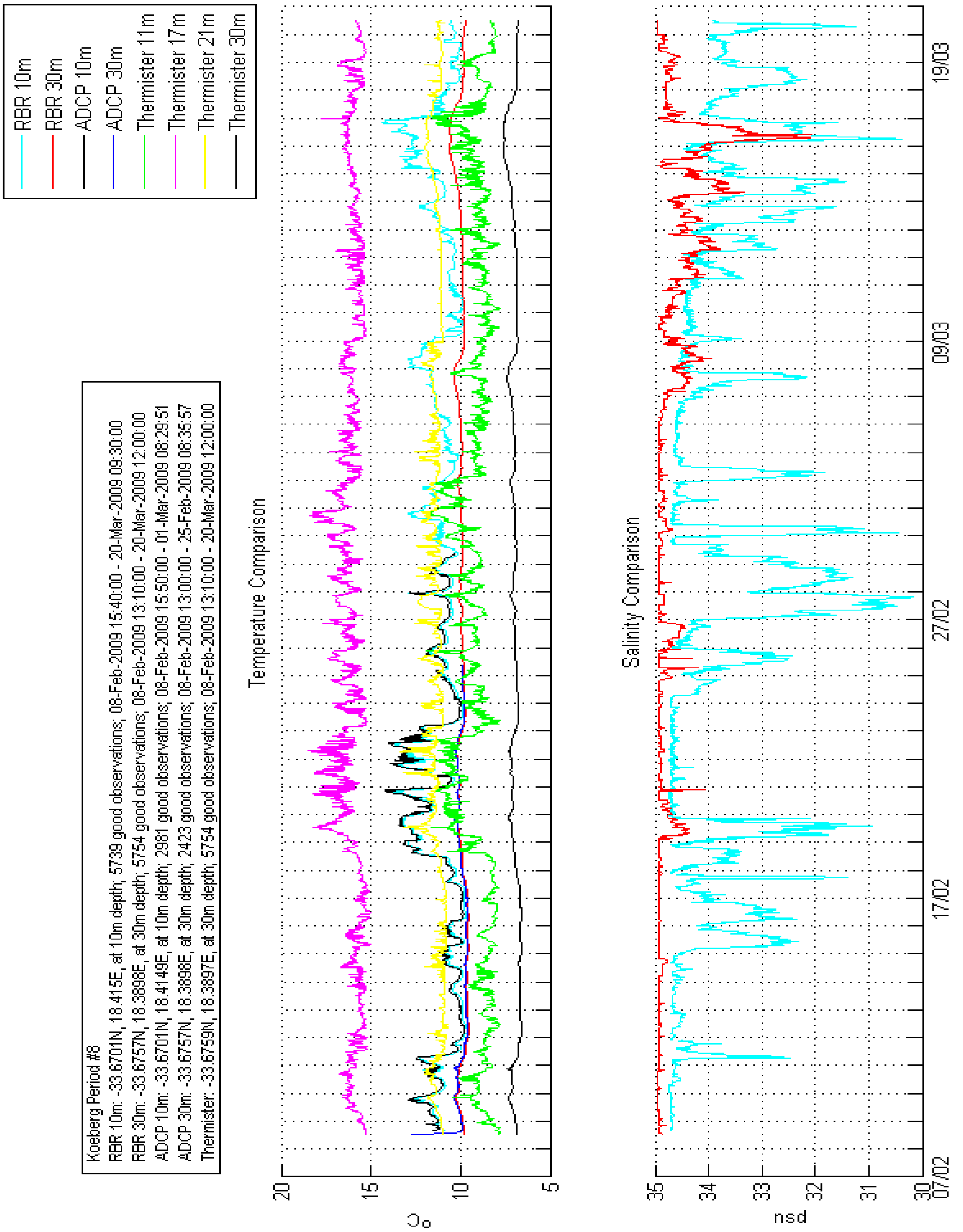


Figure 4: Time series of temperature and salinity from the RBR logger and ADCPs.

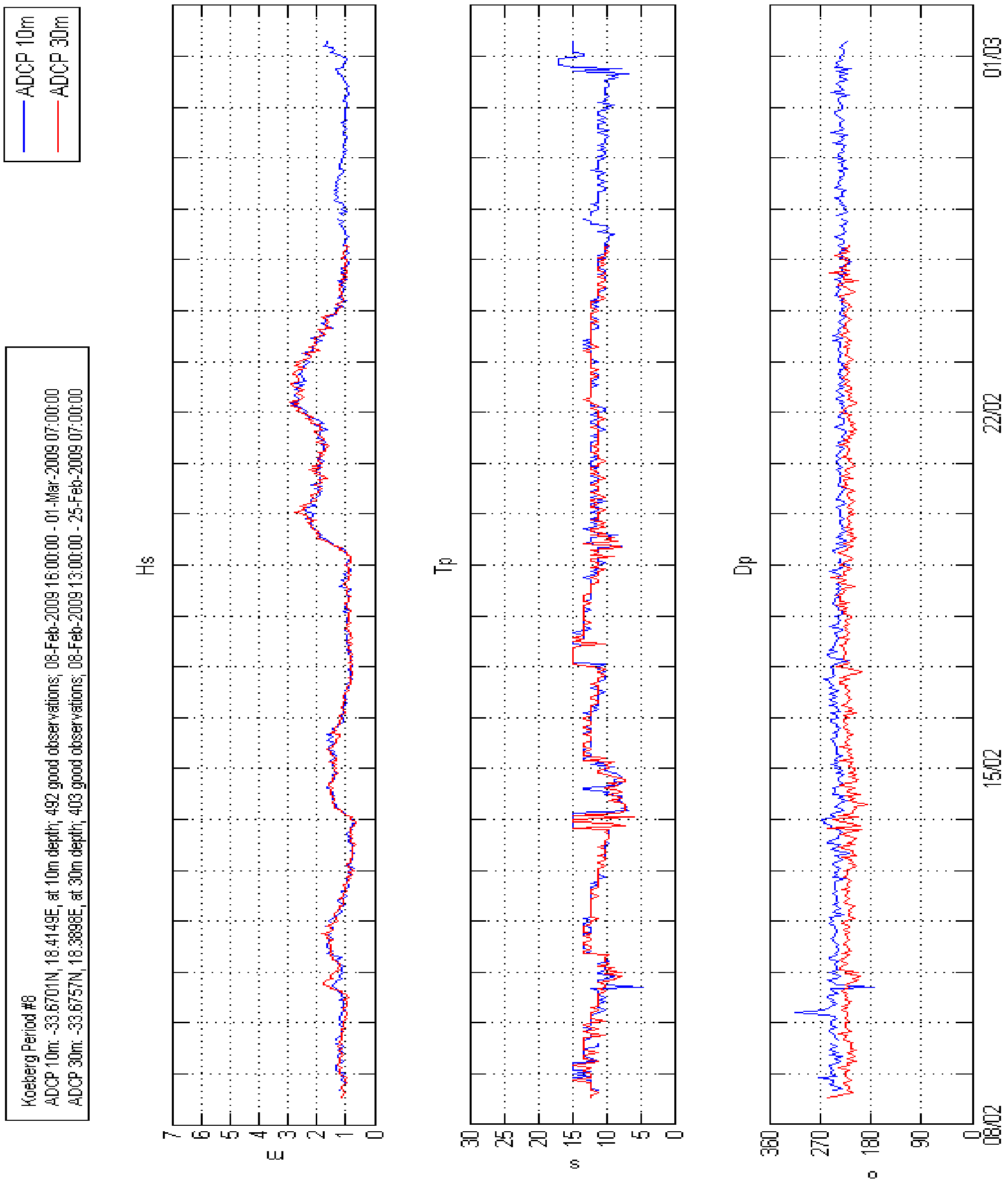


Figure 5: Time series of Hs, Tp (peak period) and Dp (Direction at Tp) from 10m and 30m ADCP

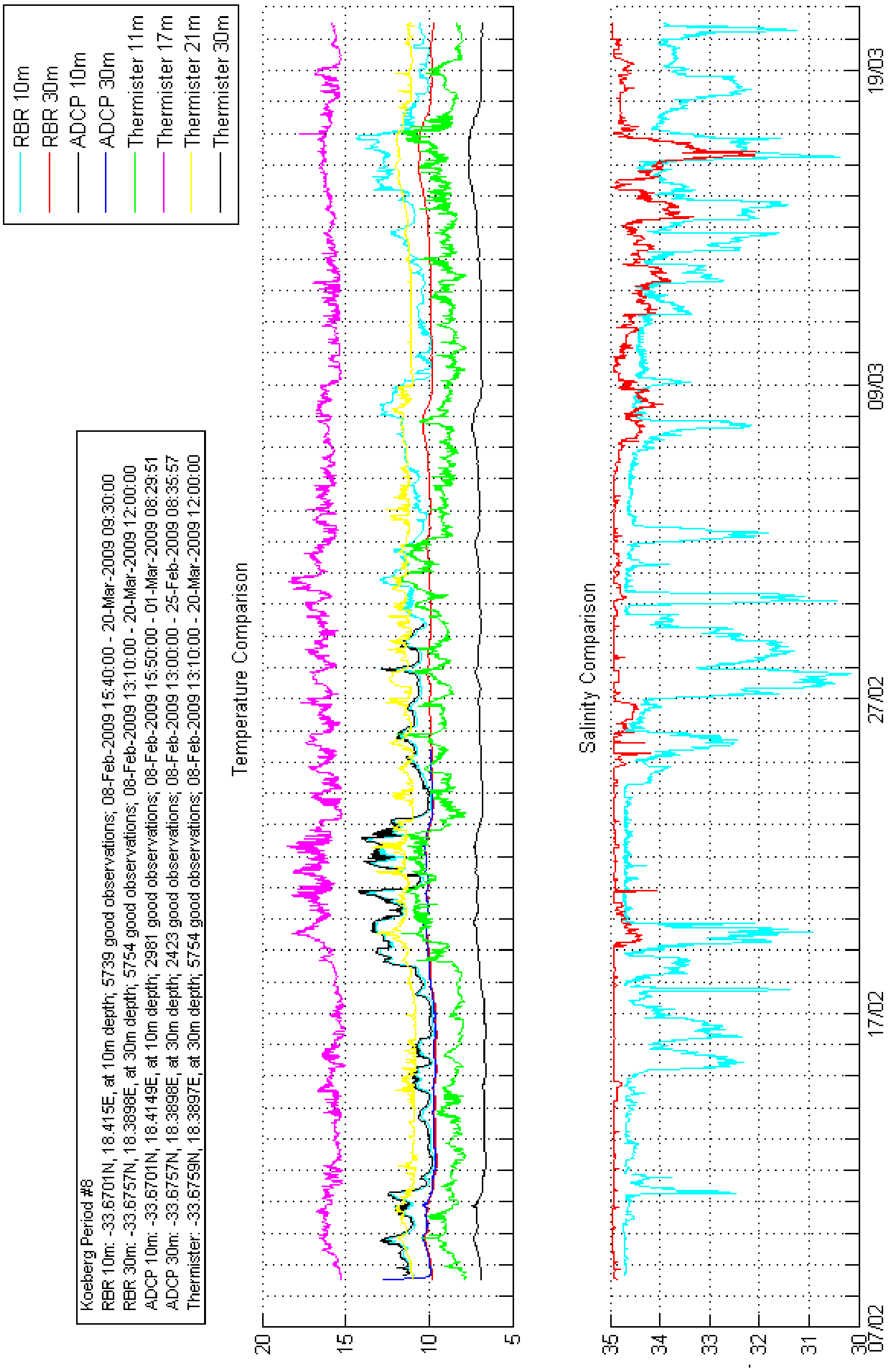


Figure 6: Time series of temperature and salinity from the RBR loggerss and ADCPs

7. INSTRUMENT PARTICULARS

7.1 ADCP RECOVERY AND RE-DEPLOYMENT SHEETS

10m ADCP.

1. **RECOVERY** **Site Name: Koeberg 10m** **Date: 24 March 2009**

Instrument type and serial number			RDI	10841
Recovery date and time	LTx	GMT	**24 March 2009 17:40**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LTx	GMT	25 March 2009 07:15	
File size			Sn#2 K1002 191MB	
Was the data copied to memory card?			File Unreadable	N

2. **RE-DEPLOYMENT** **Site Name: Koeberg 10m** **Date : 3 April 2009**

Instrument type and serial number (do not ignore – if same, please indicate)	RDI	**10841**
Install a new battery and/or check the voltage		**1*44.6V**
Frequency of unit being used	**600KHz**	
Depth range	**10m**	
Number of bins (calculated automatically)	**42**	
Bin Size (calculated automatically)	**0.35**	
Wave burst duration	**40 min**	
Time between wave bursts	**60min**	
Pings per ensemble	**500**	
Ensemble interval	**10min**	
Deployment duration	**13 days**	
Transducer depth	**10m**	
Any other commands	**RI0,FD,minTP**	
Temperature	**5**	
Recorder size	**Sn#4 1GByte**	

Consequences of the sampling parameters

First and last bin range			**1.41**	**15.76**
Battery usage				**376Wh**
Standard deviation				**1.08**
Storage space required				**113MB**
Set the ADCP clock	LT-x	GMT	**2 April 2009 17:08**	
Run pre-deployment tests				**Yes**
Name the ADCP deployment			**K1004**	

Deployment details

Switch on date and time	LTx	GMT	**2 April 2009 17:08**
Deployment date and time	LTx	GMT	**3 April 2009 09:00**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.207**

Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.894**
Site depth	10m	Deployment depth	**9.6m**
Acoustic release (1) serial number and release code			
Acoustic release (2) serial number and release code			
Argos beacon serial number			**-**
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**K1004**

30m ADCP.

1. RECOVERY Site Name: Koeberg 30m Date: . 24 March 2009

Instrument type and serial number		RDI	10119
Recovery date and time	LTx	GMT	**24 March 2009 16:55**
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Switch off date and time	LTx	GMT	25 March 2009 07:20
File size			Sn#3 K3002 156MB
Was the data copied to memory card?		File Unreadable	N

2. **RE-DEPLOYMENT Site Name: Koeberg 30m Date: 3 April 2009.**

Instrument type and serial number (do not ignore – if same, please indicate)		RDI	**10119**
Install a new battery and/or check the voltage			**1*44.9V**
Frequency of unit being used			**600KHz**
Depth range			**30m**
Number of bins (calculated automatically)			**69**
Bin Size (calculated automatically)			**0.5**
Wave burst duration			**40min**
Time between wave bursts			**60min**
Pings per ensemble			**250**
Ensemble interval			**10min**
Deployment duration			**13 days**
Transducer depth			**30m**
Any other commands			**RI0,minTP**
Temperature			**5**
Recorder size			**Sn#1 - 1GByte**

Consequences of the sampling parameters

First and last bin range		**1.6**	**35.6**
Battery usage			**435Wh**
Standard deviation			**0. 86**
Storage space required			**114MB**
Set the ADCP clock	LT-x	GMT	**2 April 2009 17:01**
Run pre-deployment tests			**Yes**
Name the ADCP deployment			**K3004**

Deployment details

Switch on date and time	LT-x	GMT	**2 April 2009 17:01**

Deployment date and time	LT-x	GMT	**3 April 2009 08:48**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**
Site depth	30m	Deployment depth	**29.6**
Acoustic release (1) serial number and release code			**32385**
Acoustic release (2) serial number and release code			
Argos beacon serial number			
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)			**K3004**

7.2 RBR-CT LOGGERS RECOVERY AND RE-DEPLOYMENT SHEETS

10m Logger.

1. **RECOVERY** **Site Name: Koeberg 10m** **Date : 24 March 2009**

Instrument type and serial number		XR 420	12995
Recovery date and time	LTx	GMT	**24 March 2009 17:40**
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**
Switch off date and time	LT	GMT	25 March 2009 07:26
File size			125 KB
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 24 March 2009/RBR_RecoveredData

2. **RE-DEPLOYMENT** **Site Name: Koeberg 10m** **Date: 3 April 2009**

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12995
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	2 April 2009	20:46:30
End of logging (date / time)	12 May 2009	12h00
Memory usage		.4%
Battery usage		999mAH

Deployment details

Deployment date and time	LT	GMT	3 April 2009 09:00
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.207**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.894**
Site name			Koeberg 10m
Site depth			10m
Deployment depth			9.6m
Acoustic release (1) serial number and release code			**-**

Acoustic release (2) serial number and release code		-
Argos beacon serial number	-	
Save *log* file (filename format: ***serialnumber_date***)	Koeberg 3 April 2009/RBR_RecoveredData/**012995**	

30m Logger.

1. RECOVERY Site Name: Koeberg 30m Date: 18 Dec 2008.

Instrument type and serial number			XR 420	12997
Recovery date and time	LT	GMT	**24 March 2009 16:55**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.397**	
Switch off date and time	LT	GMT	25 March 2009 07:30	
File size			125 KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 24 March 2009/RBR_RecoveredData	

2. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 3 April 2009

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12997
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	2 April 2009	20:48:30
End of logging (date / time)	12 May 2009	12h00
Memory usage		.4%
Battery usage		999mAH

Deployment details

Deployment date and time	LT - x	GMT	3 April 2009 08:48
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.397**
Site name			Koeberg 30m
Site depth			30m
Deployment depth			29.6m
Acoustic release (1) serial number and release code			-
Acoustic release (2) serial number and release code			-
Argos beacon serial number			-
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 3 April 2009/RBR_RecoveredData/**012997.log**

7.3 THERMISTOR STRING RECOVERY AND RE-DEPLOYMENT SHEETS

1. RECOVERY Site Name: Koeberg 30m Date: 24 March 2009

Instrument type and serial number			XR 420 T4	15135
Recovery date and time	LT	GMT	**24 March 2009 16:55**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.553**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.384**	
Switch off date and time	LT	GMT	25 March 2009 07:34	
File size			284KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 24 March 2009/RBR_RecoveredData **/015135.log**	

2. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 3 April 2009

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420 T4	15135
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	2 April 2009	20:50:20
End of logging (date / time)	12 May 2009	12h00
Memory usage		1.7%
Battery usage		62mAH

Deployment details

Deployment date and time	LT - x	GMT	3 April 2009 08:48	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.553**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.384**	
Site name			Koeberg 30m	
Site depth			30m	
Deployment depth			29.6	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 3 April 2009/RBR_RecoveredDat a**/015135.log**	

7.4 ADCP CONFIGURATION FILES

10m ADCP.

```
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4800
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 312.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 113.20 MB (118698528 bytes)
;Power usage         = 376.92 Wh
;Battery usage       = 0.8
;Samples / Wv Burst = 4800
;Min NonDir Wave Per= 1.85 s
;Min Dir Wave Period= 2.49 s
```

```
;Bytes / Wave Burst = 374480
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

30m ADCP.

```
CR1
CF11101
EA0
EB0
ED300
ES35
EX11111
EZ1111111
RI0
WA255
WB0
WD111100000
WF88
WN69
WP250
WS50
WV175
HD111000000
HB5
HP4800
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 312.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.60 m
;Last cell range     = 35.60 m
;Max range           = 38.22 m
;Standard deviation = 0.86 cm/s
;Ensemble size       = 1534 bytes
```

```
;Storage required   = 114.16 MB (119709408 bytes)
;Power usage        = 435.03 Wh
;Battery usage      = 1.0
;Samples / Wv Burst = 4800
;Min NonDir Wave Per= 2.59 s
;Min Dir Wave Period= 4.31 s
;Bytes / Wave Burst = 374480
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

CERTIFICATE OF ANALYSIS

Our ref: H:\USERS\MARLAB\REPORTS\Malr2971
Report Number: MALR2971
17 April 2009

Lwandle Technologies
Gabriel Place
1 Gabriel Road
Plumstead
7800

Attention Dr Robin Carter
CHEMICAL ANALYSIS: seawater samples (Order No.: PRDW)
Samples received: 15/04/09
Analysis completed: 16/04/09
Sample description: Seawater samples in sealed plastic bottles.

Lab No	Sample Id	Total Suspended Solids in mg/L
35987	**K1**	*4*
35988	**K2**	*7*
35989	**K3**	*5*
35990	**K4**	*7*
35991	**K5**	*4*
35992	**K6**	*4*
35993	**K7**	*16*
35994	**K8**	*18*
35995	**K9**	*19*
35996	**K10**	*13*
35997	**K11**	*7*

Andrew Pascall
MARINE ANALYTICAL SERVICES
Laboratory Manager

Sebastian Brown
MARINE ANALYTICAL SERVICES
Deputy Laboratory Manager

- Method not included in the scope of accreditation.

LWANDLE DATA REPORT

KOEBERG SITE – TURBIDITY DATA

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

28 August 2009

Job No: LT-JOB-50

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1. INTRODUCTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents the turbidity data calculated for the Koeberg site for the period 16th January 2008 –1st March 2009.

2. DATA AND METHOD.

The turbidity values were derived using the ADCP data collected at the Koeberg 10m site as well as the water samples collected during the service visits. The *ViSea Plume Detection Toolbox* enables one to quantify suspended sediment from ADCP backscatter data. The reflections of the acoustic signals from particles in the water column provide an indication about the presence of suspended sediment concentration (SSC). Calibration measurements are provided from water samples collected. The conversion method takes into account the influences on sound absorption by variable sediment concentrations in different layers. The accuracy of the output is strongly influenced by the quality and number of the calibration measurements available.

Methods:

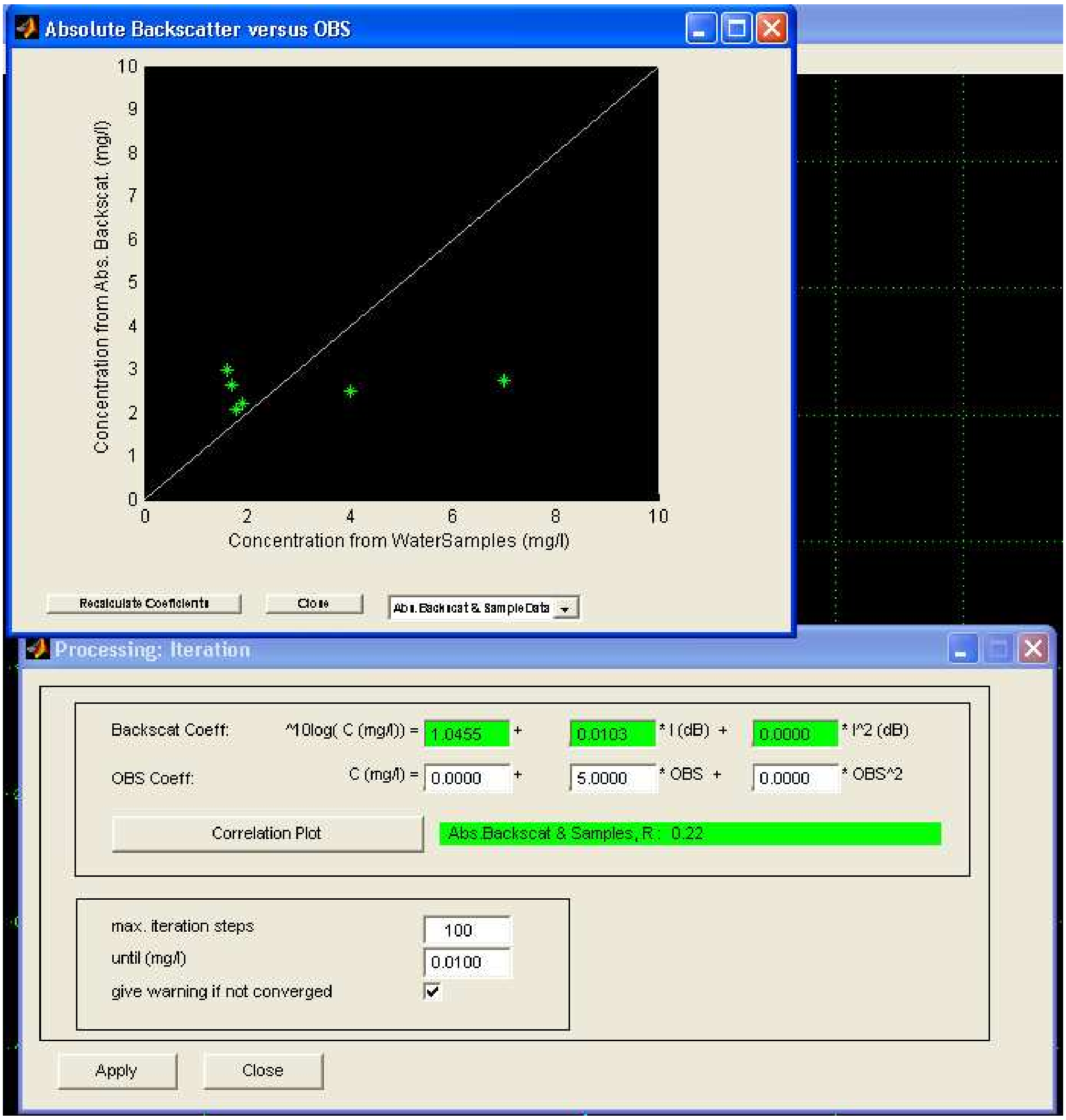
1. Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves.
2. Current data were then loaded into the ViSea toolbox.
3. Water sample collected during service visits were used for calibration.

Table 1: Water samples collected during service visits 3, 4, and 5 and subsequently analysed at the CSIR. These values were used as calibration.

Lab No	Sample Id	Date	Total Suspended Solids in mg/L	Lat	Lon
37089	Koeberg s5-4m	11/07/08	1.9	33.40.206	18.24.897
37090	Koeberg s6-8m	11/07/08	1.8	33.40.206	18.24.897
34862	Koeberg-1	19/10/08	1.7	33.40.206	18.24.897
34864	Koeberg-2	19/10/08	1.6	33.40.206	18.24.897
35237	K5-8m	06/12/08	4	33 40.206	18 24.897
35238	K6-4m	06/12/08	7	33 40.206	18 24.897

3. DATA PRESENTATION AND DISCUSSION.

The backscatter coefficients are calculated by means of calibration with reference measurements.



Backscat Coeff: ^10log(C (mg/l)) = 1.0455 + 0.0103 * I (dB) + 0.0000 * I^2 (dB)

OBS Coeff: C (mg/l) = 0.0000 + 5.0000 * OBS + 0.0000 * OBS^2

Abs Backscat & Samples, R : 0.22

max. iteration steps 100

until (mg/l) 0.0100

give warning if not converged ☑

Figure 1: (a) the relation between the SSC reference measurements and SSC calculated from the absolute backscatter from the selected beam 1. (b) The optimisation of the calculated SSC is achieved after a maximum of 100 iterations within 0.01 mg/L accuracy.

The resulting correlation coefficient is 0.22. The following figures show the suspended sediment concentrations (*mg/L*) for the period 16th January 2008 –1st March 2009.

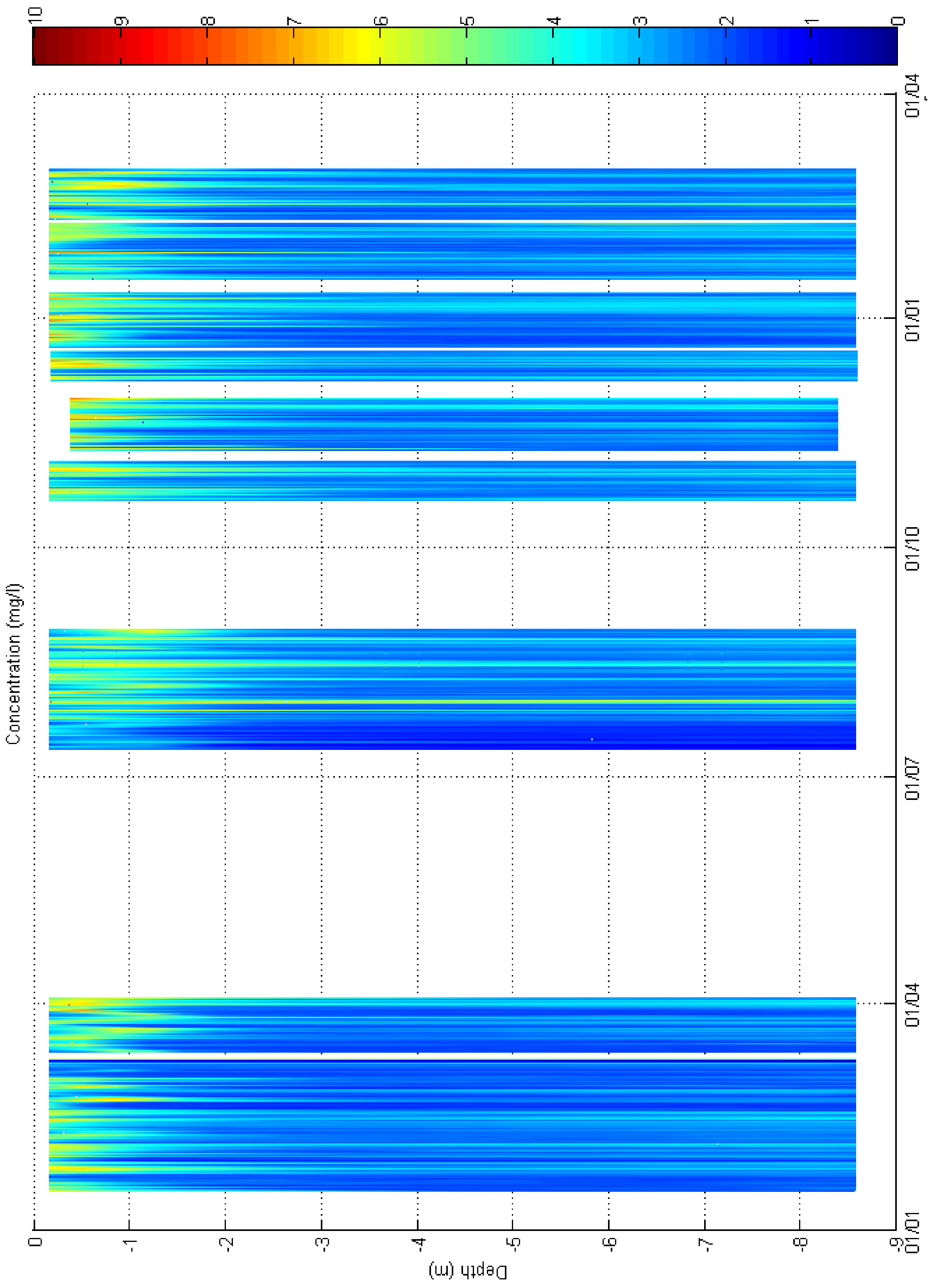


Figure 2: Turbidity concentrations (mg/l) at the Koeberg 10m ADCP site from January 2008 to March 2009.

The turbidity values are generally less than 5mg/l per litre at Koeberg. Over a period 16th January 2008 –1st March 2009, 12 water samples were taken at the 10m ADCP site. Some of these samples could not be used for the correlation. These include 4 samples taken with no ADCP correspondence and 2 samples deemed wrong as a result of laboratory errors. The higher the number of usable water samples the better the correlation.

LWANDLE TECHNOLOGIES (PTY) LTD

LWANDLE DATA REPORT

KOEBERG SITE – DEPLOYMENT NINE

PREPARED FOR
PRESTEDGE RETIEF DRESNER WIJNBERG (PTY) LTD

PREPARED BY
LWANDLE TECHNOLOGIES (PTY) LTD

28 August 2009

Job No: LT-JOB-50

Directors: C.P. Matthysen, M. Majodina, B.J. Spolander

LWANDLE TECHNOLOGIES (PTY) LTD
Unit 13/15 Constantia Business Park, Princess Vlei Road,
Diep River, 7800, South Africa

Co Reg. No. 2003/015524/07

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1. DISCLAIMER

The data is this report will undergo additional quality control procedures by Prestedge Retief Dresner Wijnberg (PRDW). For this reason no data in this report should be used for design purposes and only quality controlled data provided by PRDW should be used.

2. EXECUTIVE SUMMARY

First order statistics of the data collected at Koeberg during deployment 9 are presented in this section together with an indication of the data return achieved.

Table 1 – Current flow summary for 10m ADCP

Depth (m)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (°)
-7.9	0.3093	0.0557	0.0401	0.0112	158.73
-7.5	0.3152	0.0570	0.0419	0.0116	156.75
-7.2	0.3181	0.0584	0.0436	0.0119	159.84
-6.8	0.3188	0.0599	0.0438	0.0127	160.47
-6.5	0.3189	0.0614	0.0453	0.0129	165.47
-6.1	0.3226	0.0630	0.0463	0.0128	167.71
-5.8	0.3191	0.0647	0.0474	0.0127	174.27
-5.4	0.3459	0.0668	0.0493	0.0123	180.21
-5.1	0.3577	0.0683	0.0507	0.0122	189.70
-4.7	0.3497	0.0694	0.0521	0.0118	199.77
-4.4	0.3655	0.0711	0.0545	0.0124	213.82
-4.0	0.3678	0.0728	0.0556	0.0130	223.91
-3.7	0.3734	0.0752	0.0578	0.0144	233.29
-3.3	0.3953	0.0782	0.0595	0.0167	242.62
-3.0	0.4215	0.0807	0.0612	0.0186	250.03
-2.6	0.4260	0.0836	0.0635	0.0218	257.35
-2.3	0.4682	0.0870	0.0655	0.0249	261.28
-1.9	0.4493	0.0908	0.0673	0.0269	264.39
-1.6	0.4580	0.0935	0.0695	0.0275	272.36
-1.2	0.4761	0.0962	0.0705	0.0233	292.14
-0.9	0.5238	0.0975	0.0681	0.0151	324.81

Table 2 – Waves summary for 10m ADCP

	Max	Min	Mean	Std
Hs (m)	1.49	0.26	0.76	0.31
Tp (s)	9.50	5.70	9.14	0.67
Dp (^{o})	281.70	173.7	238.85	9.09

Table 3 – Current flow summary for 30m ADCP

Depth (m)	Max speed (ms^{-1})	Mean speed (ms^{-1})	Std speed (ms^{-1})	Vector mean speed (ms^{-1})	Vector mean direction (^{o})
-26.3	0.1317	0.0379	0.0201	0.0137	157.71
-25.8	0.1367	0.0401	0.0211	0.0153	157.96
-25.3	0.1382	0.0425	0.0219	0.0171	157.13
-24.8	0.1673	0.0438	0.0226	0.0182	156.77
-24.3	0.1419	0.0455	0.0234	0.0197	155.96
-23.8	0.1434	0.0467	0.0241	0.0204	154.87
-23.3	0.1502	0.048	0.0247	0.0214	154.42
-22.8	0.1545	0.0483	0.0251	0.0219	153.28
-22.3	0.1503	0.0491	0.0253	0.0228	153.18
-21.8	0.1460	0.0501	0.0255	0.0235	152.98
-21.3	0.1533	0.0508	0.0260	0.0236	151.96
-20.8	0.1529	0.0509	0.0263	0.0236	149.93
-20.3	0.1560	0.0519	0.0265	0.0239	149.83
-19.8	0.1651	0.053	0.0273	0.0243	148.56
-19.3	0.1544	0.0538	0.0272	0.0245	147.05
-18.8	0.1597	0.0548	0.0277	0.0245	146.18
-18.3	0.1623	0.0557	0.0281	0.0251	144.60
-17.8	0.1665	0.0567	0.0286	0.0254	142.69
-17.3	0.1620	0.0581	0.0285	0.0259	141.26
-16.8	0.1649	0.0591	0.0295	0.0263	140.20
-16.3	0.1626	0.0602	0.0303	0.0263	138.77
-15.8	0.1690	0.0609	0.0306	0.0261	137.17
-15.3	0.1659	0.0615	0.0315	0.0259	136.44
-14.8	0.1648	0.0623	0.0325	0.0252	135.16
-14.3	0.1713	0.0628	0.0331	0.0247	134.54
-13.8	0.1799	0.0632	0.0341	0.0237	133.75
-13.3	0.1704	0.0639	0.0344	0.0227	135.16
-12.8	0.1861	0.0647	0.0351	0.0217	135.11
-12.3	0.1944	0.0651	0.0360	0.0199	136.56
-11.8	0.2097	0.0659	0.0368	0.0184	136.84
-11.3	0.1950	0.0671	0.0381	0.0170	137.45
-10.8	0.1983	0.0682	0.0390	0.0152	138.78
-10.3	0.2040	0.0698	0.0401	0.0132	141.47
-9.8	0.2183	0.0709	0.0416	0.0113	148.16
-9.3	0.2219	0.0726	0.0426	0.0098	158.46
-8.8	0.2310	0.0744	0.0444	0.0078	174.60
-8.3	0.3120	0.0760	0.0457	0.0073	189.82
-7.8	0.2595	0.0784	0.0470	0.0067	215.25
-7.3	0.2673	0.0805	0.0488	0.0073	233.38
-6.8	0.2713	0.0835	0.0505	0.0086	250.88
-6.3	0.2894	0.0860	0.0524	0.0106	262.61

-5.8	0.3108	0.0877	0.0549	0.0133	275.42
-5.3	0.3437	0.0899	0.0569	0.0169	280.55
-4.8	0.3621	0.0924	0.0595	0.0210	287.75
-4.3	0.4070	0.0942	0.0613	0.0252	291.56
-3.8	0.3831	0.0958	0.0629	0.0278	295.90
-3.3	0.4096	0.0969	0.0617	0.0233	304.87
-2.8	0.4499	0.1017	0.0589	0.0205	347.20
-2.3	0.4459	0.1085	0.0636	0.0391	23.93
-1.8	0.3502	0.1100	0.0623	0.0598	21.97

Table 4 – Waves summary for 30m ADCP

	Max	Min	Mean	Std
Hs (m)	1.85	0.34	0.93	0.32
Tp (s)	19.60	4.80	9.13	0.88
Dp (^{o})	286.70	204.70	231.89	12.28

Table 5 – Water temperature and salinity summary for 10m RBR logger

Parameter	Mean	Max	Min
Temperature (^{o}C)	10.93	12.80	10.08
Conductivity	38.48	40.44	24.85
Salinity (psu)	34.70	34.85	30.66

Table 6 – Water temperature and salinity summary for 30m RBR logger

Parameter	Mean	Max	Min
Temperature (^{o}C)	10.19	10.68	9.93
Conductivity	38.05	38.62	31.14
Salinity (psu)	34.79	34.97	33.74

2.1 DATA RETURN FOR KOEBERG SITE.

Table 7 – Data Return (%).

Koeberg P09	16 January 2008 / 11 July 2008 – 15 January 2009	15 January 2009 – 25 April 2009	3 April 2009 – 25 April 2009
Btm RBR Salinity	67	87	100
Surf RBR Salinity	48	69	100
10m ADCP Current	55	65	96
10m ADCP Wave	55	65	96
30m ADCP Current	57	57	83
30m ADCP Wave	56	57	83
Thermistor String	15	63	100
Temp-Btm RBR	68	87	100
Temp-Surf RBR	49	87	100
Temp-10m ADCP	55	65	96
Temp-30m ADCP	57	57	83
30m Temperature	77	87	100
10m Temperature	79	87	100

3. INTRODUCTION

3.1 PROJECT DESCRIPTION

Lwandle Technologies (Pty) Ltd has been contracted by Prestedge Retief Dresner Wijnberg (PRDW) for oceanographic measurements in connection with the Eskom preliminary site safety report. Oceanographic data is required as input to the coastal engineering studies for a proposed new nuclear power station at three potential sites, Koeberg, Bantamsklip and Thyspunt. This data will be measured for a period of 31 months.

This report presents waves, currents, temperature and salinity data collected at Koeberg station for the period April 3rd – 25th 2009. Service of the instruments was undertaken on: April 24th and 25th 2009.

3.2 MEASUREMENT LOCATION

Table 8 – Initial deployment locations.

Instrument	Latitude (°S)	Longitude (°E)
10m ADCP and RBR logger.	33.6701	18.4149
30m ADCP and RBR logger	33.6757	18.3898
Thermistor string	33.6759	18.3097

Table 9 – Water Samples taken on April 24-25th 2009

Bottle #	STN #	Lat	Long	Exact Time HH:MM:SS	COMMENTS (if RBR profile is taken etc..)
1	30m	33 40.540	18 23.387	14:22	Depth: 4m
2	30m	33 40.540	18 23.387	14:23	Depth: 12m
3	30m	33 40.540	18 23.387	14:25	Depth: 20m
4	30m	33 40.540	18 23.387	14:27	Depth: 28m
5	10m	33 40.207	18 24.894	14:52	Depth: 4m
6	10m	33 40.207	18 24.894	14:55	Depth: 8m
7	1	33 40.511	18 25.381	15:11	Depth: 4m
8	2	33 40.447	18 25.403	15:14	Depth: 4m
9	3	33 40.375	18 25.402	15:15	Depth: 4m
10	4	33 40.344	18 25.389	15:17	Depth: 4m
11	5	33 40.332	18 25.335	15:19	Depth: 4m

4. OPERATIONS

4.1 SUMMARY OF EVENTS

Service of the instruments was undertaken on April 24th – 25th 2009. Water samples were taken.

4.2 INSTRUMENT CONFIGURATIONS

Configurations were as per specifications.

Note: Biofouling plates have been installed on frame to avoid third party interference (as of May 2009).

5. DATA QUALITY CONTROL

5.1 ADCP

Raw binary files were processed using the WavesMon software to separate the data into two components: currents and waves. Matlab was then used to process the data further.

5.1.1 Current processing

- The record was truncated to exclude times pre and post deployment.
- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 18'W (both ADCP sites).
- A flag was imposed on all data within 6% of the waters surface due to side lobe interference. The distance to the water surface was based on the ADCP's pressure sensor.
- Checks were then run searching for any outliers in the velocity data. This was automated within a routine that compared the median of 5 values to the centre point. A tolerance of 0.2ms^{-1} was allowed. Outliers identified by this method were then visually examined and flagged.
- Checks were then run searching for repeated values in the velocity and direction data. This was automated within a routine that searched for 3 identical consecutive values.
- The ADCP attitude data (heading, pitch and roll) were examined.
- Finally, all flagged data were replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

5.1.2 Wave processing

Wave parameters Hs (significant wave height), Tp (period of peak energy) and Dp (direction with peak energy at Tp) as well as the full wave directional spectra were then imported into Matlab for further processing:

- Directions were adjusted from magnetic to true north using a magnetic variation of 24° 18' W (both ADCP sites).
- Significant wave height data below 0m were removed and replaced with the Matlab NaN symbol, ensuring that they would be excluded from all further processing.

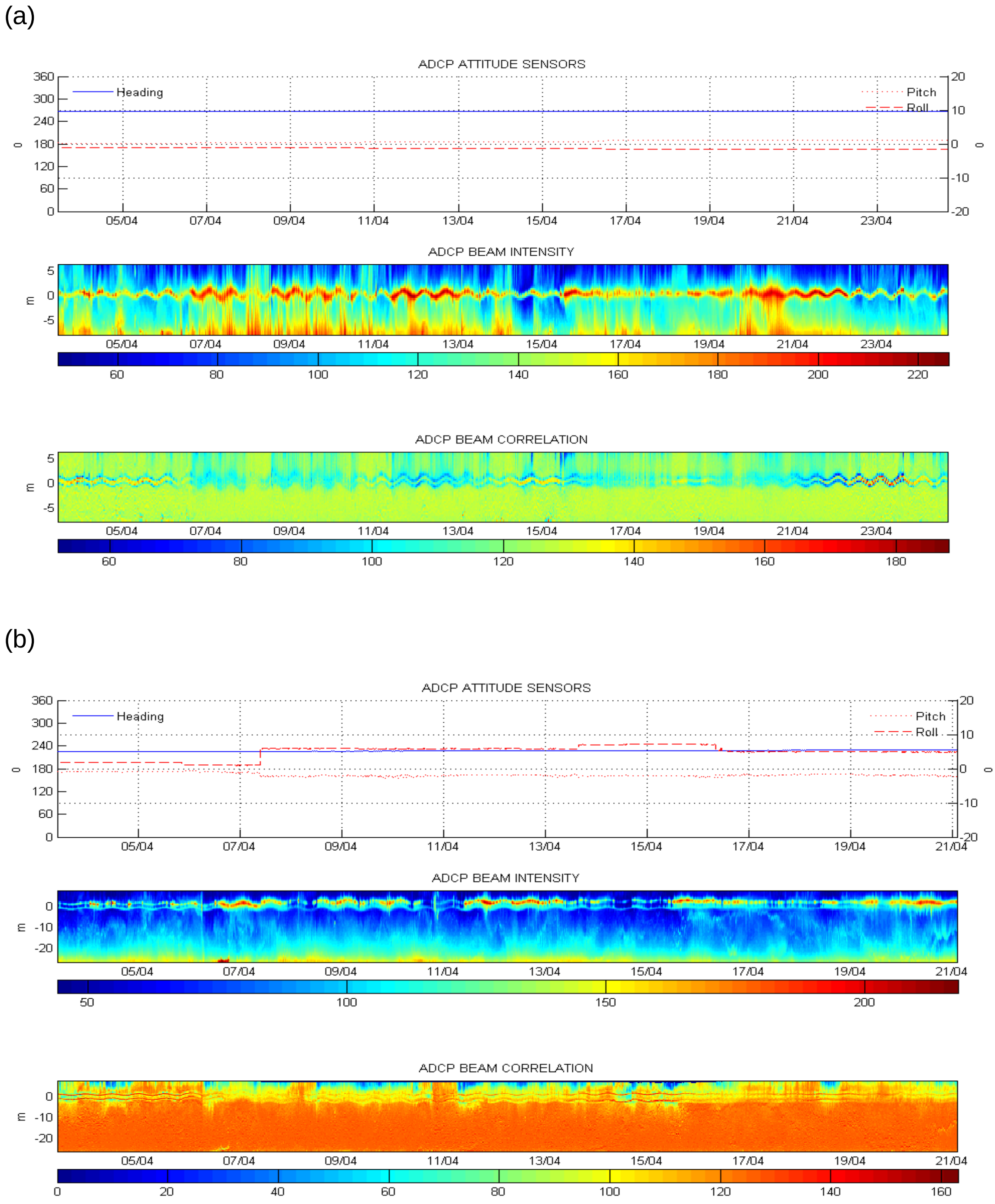


Figure 1: Quality control data from the (a) 10m and (b) 30m ADCPs. The upper panel shows the sensor attitude data (heading scaled to the left axis and pitch and roll to the right axis). The middle panel shows the time-series of ADCP beam intensity through the water column, while the lower panel shows similar information for the beam correlation.

5.2 RBR-CT LOGGER AND THERMISTER STRING

The conductivity (from the CT-logger) and temperature data were exported directly from the RBR software into Matlab for further processing.

- The record was truncated to exclude times pre and post deployment.
- The conductivity and temperature data were used to derive salinity according to the 1978 UNESCO algorithm.

5.3 BIOFOULING.

The following standard procedure is normally followed:

- The biofouling plates are retrieved.
- Photographs of the plate and prominent features are taken.
- Biofouling 'thickness' at 3 or 4 locations on the plates is measured.
- The Biofouling organisms present on the plates are gently scraped into plastic bag and transferred in water to the sample bottle.
- Formaldehyde is used to get a final 2-4% strength solution and 1 or 2 $CaCO_3$ chips are added.
- Sample bottles are stored upright in the dark.

Recovery of the biofouling plates was not scheduled.

5.4 WATER SAMPLE.

Water samples were taken and sent to CSIR for analysis.

6. DATA PRESENTATION AND DISCUSSION

The thermistor string was successfully deployed but due to its proximity to the surface we suspect it was tampered with and some nodes were damaged. Since redeployment the unit has returned data. We need to reconfigure the unit with new calibration coefficients (factory recalibration) to improve on the accuracy of the results from some of the nodes. This will happen in December 2009. The data presented here is therefore uncalibrated.

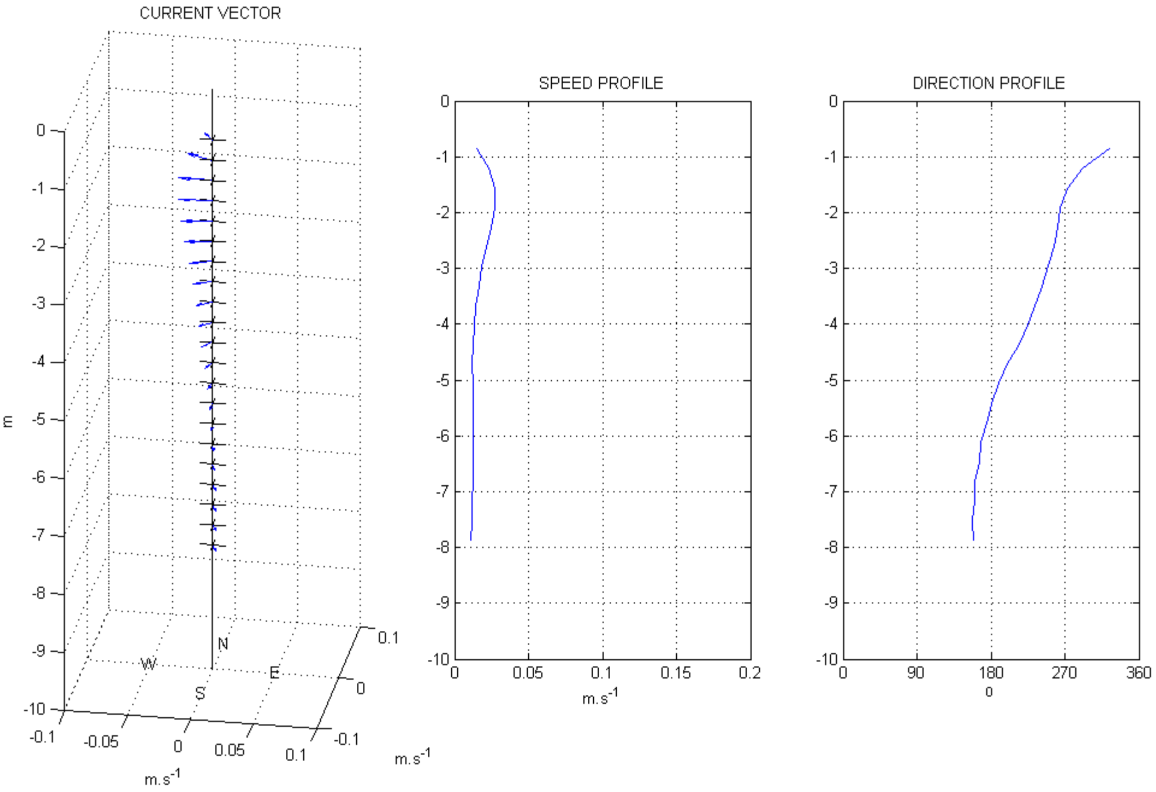


Figure 2: Mean profile plot for 10m ADCP.

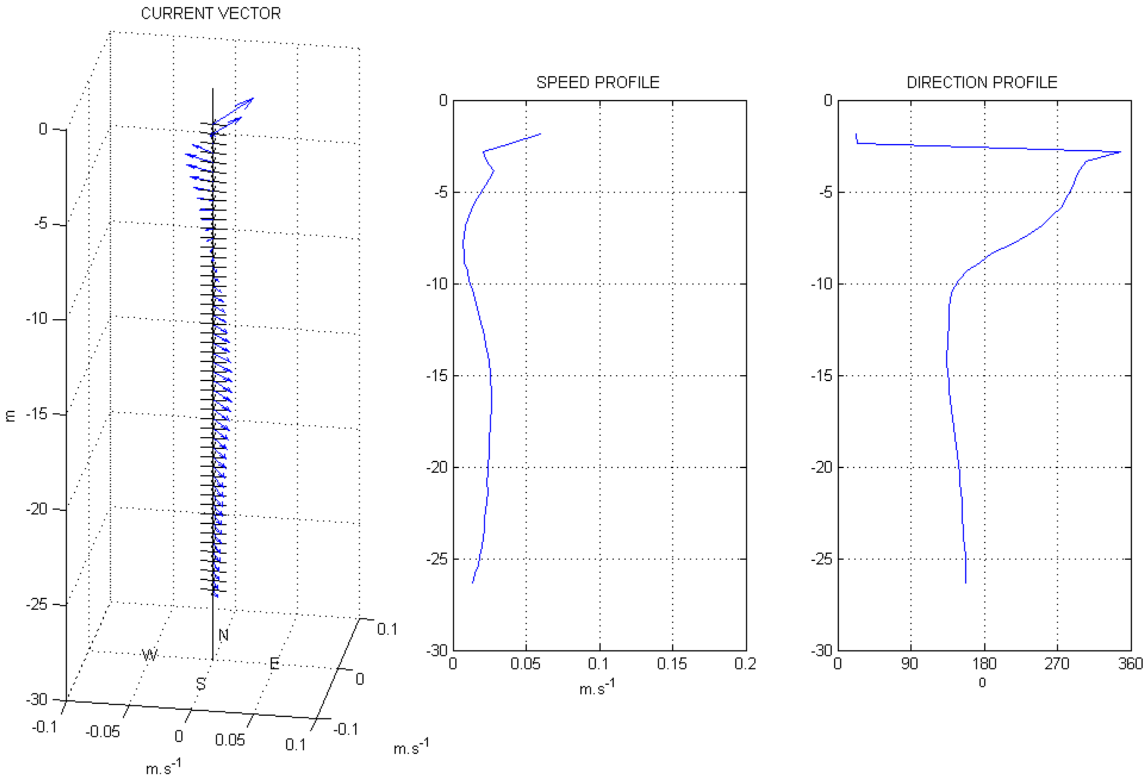
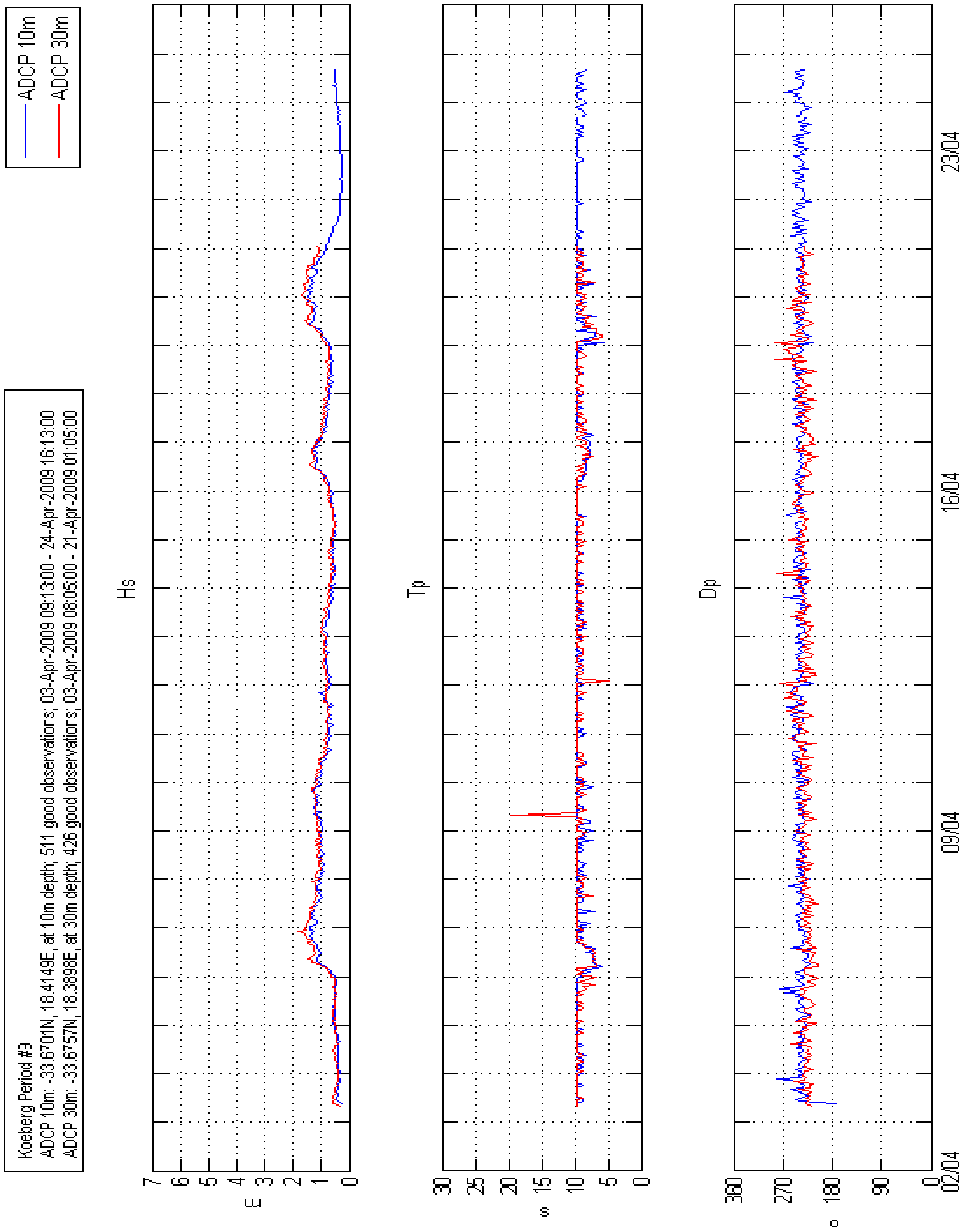


Figure 3: Mean profile plot for 30m ADCP.



FigureFigure 4: Time series of Hs, Tp (peak period) and Dp (Direction at Tp) from 10m and 30m ADCPs.

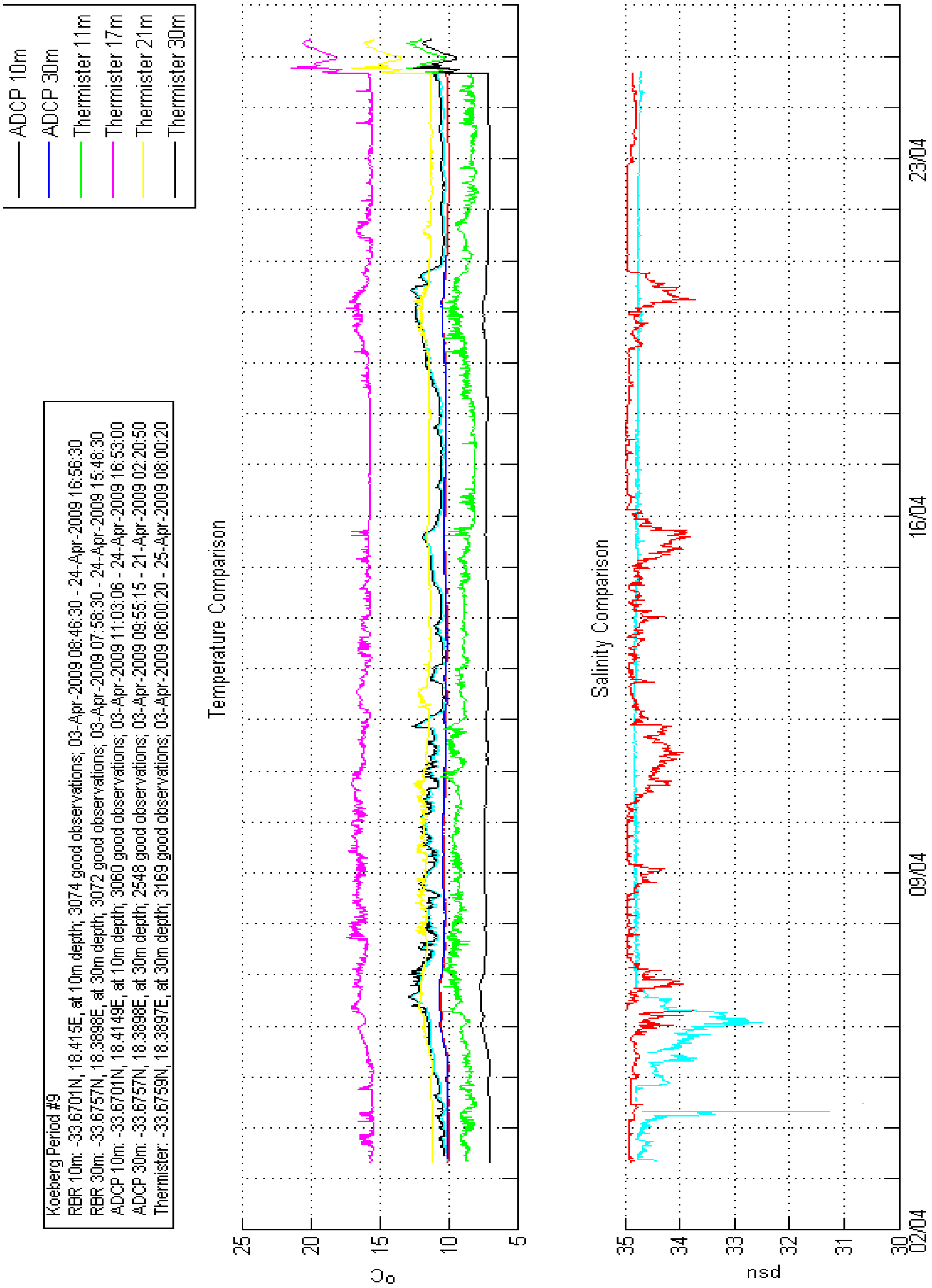


Figure 5: Time series of temperature and salinity from the RBR logger and ADCPs.

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7. INSTRUMENT PARTICULARS

7.1 ADCP RECOVERY AND RE-DEPLOYMENT SHEETS

10m ADCP.

1. **RECOVERY** **Site Name: Koeberg 10m** **Date: 24 April 2009**

Instrument type and serial number			RDI	10841
Recovery date and time	LTx	GMT	**24 April 2009 17:00**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**	
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**	
Switch off date and time	LTx	GMT	24 April 2009 07:49	
File size			206MB	
Was the data copied to memory card?			Yes	N

2. **RE-DEPLOYMENT** **Site Name: Koeberg 10m** **Date : 25th April**

Instrument type and serial number (do not ignore – if same, please indicate)			RDI	**10841**
Install a new battery and/or check the voltage				**1*44.6V**
Frequency of unit being used			**600KHz**	
Depth range			**10m**	
Number of bins (calculated automatically)			**42**	
Bin Size (calculated automatically)			**0.35**	
Wave burst duration			**40 min**	
Time between wave bursts			**60min**	
Pings per ensemble			**500**	
Ensemble interval			**10min**	
Deployment duration			**13 days**	
Transducer depth			**10m**	
Any other commands			**RI0,FD,minTP**	
Temperature			**5**	
Recorder size			**Sn#4 1GByte**	

Consequences of the sampling parameters

First and last bin range		**1.41**	**15.76**
Battery usage			**376Wh**
Standard deviation			**1.08**
Storage space required			**113MB**
Set the ADCP clock	LT-x	GMT	**25 April 2009 10:22**
Run pre-deployment tests			**Yes**
Name the ADCP deployment			**K1005**

Deployment details

Switch on date and time	LTx	GMT	**25 April 2009 10:2**
Deployment date and time	LTx	GMT	**25 April 2009 14:55**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.207**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.894**

Site depth	10m	Deployment depth	**9.6m**
Acoustic release (1) serial number and release code			
Acoustic release (2) serial number and release code			
Argos beacon serial number		**-**	
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)		**K1005**	

30m ADCP.

1. RECOVERY Site Name: Koeberg_30m Date: .24th April 2009

Instrument type and serial number			RDI	10119
Recovery date and time	LTx	GMT	**24 April 2009 16:00**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.387**	
Switch off date and time	LTx	GMT	24 April 2009 07:46	
File size			169MB	
Was the data copied to memory card?			Yes	N

2. **RE-DEPLOYMENT Site Name: Koeberg_30m Date: 25th April 2009 .**

Instrument type and serial number (do not ignore – if same, please indicate)	RDI	**10119**
Install a new battery and/or check the voltage		**1*44.9V**
Frequency of unit being used	**600KHz**	
Depth range	**30m**	
Number of bins (calculated automatically)	**69**	
Bin Size (calculated automatically)	**0.5**	
Wave burst duration	**40min**	
Time between wave bursts	**60min**	
Pings per ensemble	**250**	
Ensemble interval	**10min**	
Deployment duration	**13 days**	
Transducer depth	**30m**	
Any other commands	**RI0,minTP**	
Temperature	**5**	
Recorder size	**1 * 1GB SN#1**	

Consequences of the sampling parameters

First and last bin range		**1.6**	**35.6**
Battery usage			**435Wh**
Standard deviation			**0. 86**
Storage space required			**114MB**
Set the ADCP clock	LT-x	GMT	**25 April 2009 09:52**
Run pre-deployment tests			**Yes**
Name the ADCP deployment			**K3005**

Deployment details

Switch on date and time	LT-x	GMT	**25 April 2009 09:52**
Deployment date and time	LT-x	GMT	**25 April 2009 14:15**
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.387**

Site depth	30m	Deployment depth	**29.6**
Acoustic release (1) serial number and release code			
Acoustic release (2) serial number and release code			
Argos beacon serial number			
Save *whp*, *dpl* and *scl* files in one folder (filename format: ***serialnumber_date***)	**K3005**		

7.2 RBR-CT LOGGERS RECOVERY AND RE-DEPLOYMENT SHEETS

10m Logger.

1. **RECOVERY** **Site Name: Koeberg 10m** **Date : 24 April 2009**

Instrument type and serial number		XR 420	12995
Recovery date and time	LTx	GMT	**24 April 2009 17:00**
Latitude **(do not ignore – if same, please indicate)**			**33 40.206**
Longitude **(do not ignore – if same, please indicate)**			**18 24.897**
Switch off date and time	LT	GMT	25 April 2009 07:36
File size			71KB
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 25 April 2009/RBR_RecoveredData

2. **RE-DEPLOYMENT** **Site Name: Koeberg 10m** **Date: 25th April 2009**

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12995
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period		**10 min**
Averaging period		**1 min**
Expected deployment duration		**3 weeks**
Start of logging (date / time)	25 April 2009	09:47:00
End of logging (date / time)	4 June 2009	12h00
Memory usage		.4%
Battery usage		999mAH

Deployment details

Deployment date and time	LT	GMT	3 April 2009 09:00	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.207**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 24.894**	
Site name			Koeberg 10m	
Site depth			10m	
Deployment depth			9.6m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	

Save *log* file (filename format: ***serialnumber_date***)	Koeberg 25 April 2009/RBR_newDeployLogs

30m Logger.

1. RECOVERY   Site Name: Koeberg 30m   Date: 24th April 2009.

Instrument type and serial number			XR 420	12997
Recovery date and time	LT	GMT	**24 April 2009 16:00**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.397**	
Switch off date and time	LT	GMT	25 April 2009 07:39	
File size			71KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 25 April 2009/RBR_RecoveredData	

2. RE-DEPLOYMENT   Site Name: Koeberg 30m   Date: 25th April 2009

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420	12997
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	2 5April 2009	09:48:20
End of logging (date / time)	4 June 2009	12h00
Memory usage		.4%
Battery usage		999mAH

Deployment details

Deployment date and time	LT - x	GMT	25 April 2009 14:15	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.540**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.397**	
Site name			Koeberg 30m	
Site depth			30m	
Deployment depth			29.6m	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 25 April 2009/RBR_new_DeployLogs	

7.3 THERMISTOR STRING RECOVERY AND RE-DEPLOYMENT SHEETS

1. RECOVERY Site Name: Koeberg 30m Date: 24 April 2009

Instrument type and serial number			XR 420 T4	15135
Recovery date and time	LT	GMT	**24 April 2009 16:00**	
Latitude **(do not ignore – if same, please indicate)**			**33 40.553**	
Longitude **(do not ignore – if same, please indicate)**			**18 23.384**	
Switch off date and time	LT	GMT	25 April 2009 08:12	
File size			261KB	
Save *log*, *hex* and *dat* files in one folder (filename format: ***serialnumber_date***)			Koeberg 24 April 2009/RBR_RecoveredData	

2. RE-DEPLOYMENT Site Name: Koeberg 30m Date: 25 April 2009

Instrument type and serial number (do not ignore – if same, please indicate)	XR 420 T4	15135
Install a new battery and check the voltage		4 * 3.3

Set up the sampling parameters

Sampling period	**10 min**	
Averaging period	**1 min**	
Expected deployment duration	**3 weeks**	
Start of logging (date / time)	25 April2009	10:00:00
End of logging (date / time)	20 Mar 2009	12h00
Memory usage		1.7%
Battery usage		62mAH

Deployment details

Deployment date and time	LT - x	GMT	Failed to Deploy – 0 meter visibility	
Deployment Latitude **(do not ignore – if same, please indicate)**			**33 40.553**	
Deployment Longitude **(do not ignore – if same, please indicate)**			**18 23.384**	
Site name			Koeberg 30m	
Site depth			30m	
Deployment depth			29.6	
Acoustic release (1) serial number and release code				**-**
Acoustic release (2) serial number and release code				**-**
Argos beacon serial number			**-**	
Save *log* file (filename format: ***serialnumber_date***)			Koeberg 25 April 2009/RBR_newDeployLogs	

7.4 ADCP CONFIGURATION FILES

10m ADCP.

```
CR1
CF11101
EA0
EB0
ED100
ES35
EX11111
EZ1111111
RI0
FD
WA255
WB0
WD111100000
WF88
WN42
WP500
WS35
WV175
HD111000000
HB5
HP4800
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 312.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.41 m
;Last cell range     = 15.76 m
;Max range           = 35.28 m
;Standard deviation = 1.08 cm/s
;Ensemble size       = 994 bytes
;Storage required    = 113.20 MB (118698528 bytes)
;Power usage         = 376.92 Wh
;Battery usage       = 0.8
;Samples / Wv Burst = 4800
;Min NonDir Wave Per= 1.85 s
```

```
;Min Dir Wave Period= 2.49 s
;Bytes / Wave Burst = 374480
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

30m ADCP.

```
CR1
CF11101
EA0
EB0
ED300
ES35
EX11111
EZ1111111
RI0
FD
WA255
WB0
WD111100000
WF88
WN69
WP250
WS50
WV175
HD111000000
HB5
HP4800
HR01:00:00.00
HT00:00:00.50
TE00:10:00.00
TP00:00.50
CK
CS
;
;Instrument          = Workhorse Sentinel
;Frequency           = 614400
;Water Profile       = YES
;Bottom Track        = NO
;High Res. Modes     = NO
;High Rate Pinging   = NO
;Shallow Bottom Mode= NO
;Wave Gauge          = YES
;Lowered ADCP        = NO
;Beam angle          = 20
;Temperature         = 5.00
;Deployment hours    = 312.00
;Battery packs       = 1
;Automatic TP        = NO
;Memory size [MB]    = 1000
;Saved Screen        = 1
;
;Consequences generated by PlanADCP version 2.04:
;First cell range    = 1.60 m
;Last cell range     = 35.60 m
;Max range           = 38.22 m
```

```
;Standard deviation = 0.86 cm/s
;Ensemble size      = 1534 bytes
;Storage required   = 114.16 MB (119709408 bytes)
;Power usage        = 435.03 Wh
;Battery usage      = 1.0
;Samples / Wv Burst = 4800
;Min NonDir Wave Per= 2.59 s
;Min Dir Wave Period= 4.31 s
;Bytes / Wave Burst = 374480
;
; WARNINGS AND CAUTIONS:
; Waves Gauge feature has to be installed in Workhorse to use
selected option.
; Advanced settings have been changed.
```

CERTIFICATE OF ANALYSIS

Our ref: H:\USERS\MARLAB\REPORTS\Malr3083

Report Number: MALR3083

24 August 2009

Lwandle Technologies
Gabriel Place
1 Gabriel Road
Plumstead
7800

Attention Craig Matthysen

CHEMICAL ANALYSIS: Water samples (Order No.:)
Samples received: 20/08/09
Analysis completed: 24/08/09
Sample description: Seawater in sealed plastic bottles.

Lab No	**Sample Id**	**Total Suspended Solids in mg/L**
37352	**K1 (25/04/09)**	*12.50*
37353	**K2 (25/04/09)**	*7.8*
37354	**K3 (25/04/09)**	*<1*
37355	**K4 (25/04/09)**	*1.9*
37356	**K5 (25/04/09)**	*1.7*
37357	**K6 (25/04/09)**	*7.3*
37358	**K7 (25/04/09)**	*2.4*
37359	**K8 (25/04/09)**	*5.5*
37360	**K9 (25/04/09)**	*10.4*
37361	**K10 (25/04/09)**	*13.3*
37362	**K11 (25/04/09)**	*5.5*

Andrew Pascall
MARINE ANALYTICAL SERVICES
Laboratory Manager

Sebastian Brown
MARINE ANALYTICAL SERVICES
Deputy Laboratory Manager