Station design and construction (2020/21)

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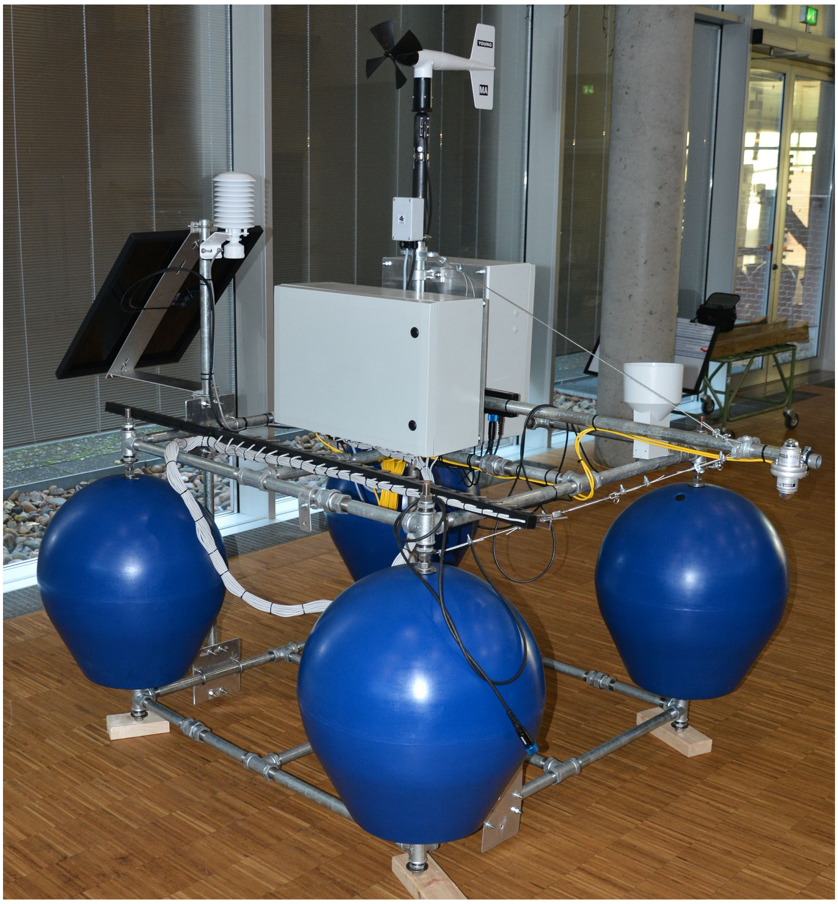

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1. Introduction

This project "**A**utomatic **C**limate and **WA**ter - **M**onitoring **S**tations" (ACWA-MS), (Danish title: Automatiske klima- og vandmiljø stationer (AKVA-MS)) consists of numerous activities and tasks. One main aim of this project is to collect continuous field data (both climate and water chemistry) over a fixed period of 3 years. The collected field data will be

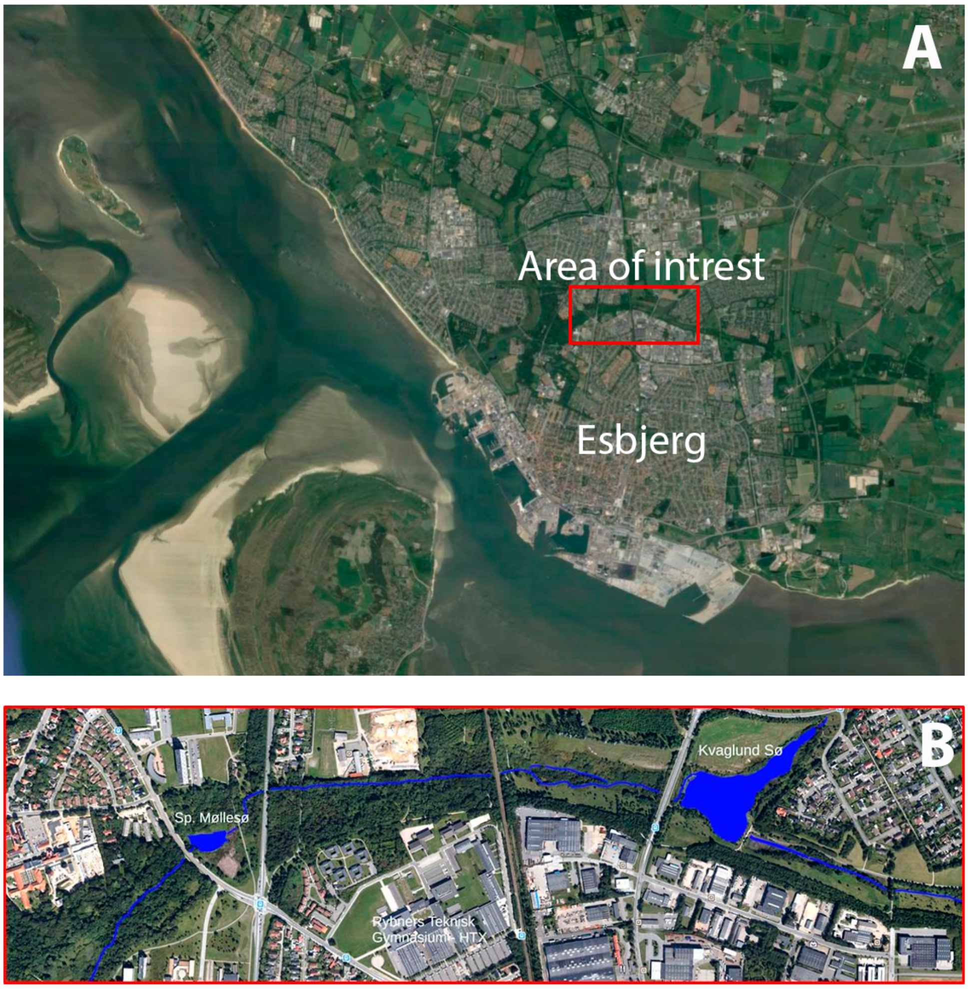

Figure 1.1: The figure (A) shows a general overview of Esbjerg town site including a red rectangle indicating the area of interest. The lower image (B) is an enlargement of the area of interest indicating the location of Kvaglund lake relative to Spangsbjerg Mølle lake. Furthermore, the location of the technical high school (Rybners HTX) is included.

basis for development of course material for a broad variety of applications and levels. Furthermore, the data material will be used for scientific analysis and cross-correlation.

The performed lake depth measurement, presented in the technical report No. 1, titled ”Lake depth measurement” from October and November 2020, is one of the preliminary tasks needed, in order to design the climate and lake water monitoring stations according to the local lake bottom topography, i.e. bathymetry.

The area of interest within Esbjerg municipality is shown in figure 1.1 (A). The area enlarged area in figure 1.1 (B) shows the particular location of Kvaglund lake and Spangsbjerg Mølle lake. Both lakes are connected with each other by Spangsbjerg Mølle creak. Finally, the location of the Technical High School (Rybners HTX) is marked, to indicate that both lakes are in the close vicinity of the school and hence easily reachable for frequent visits.

This technical report provides a complete overview over specification requirements, station design and construction as well as a complete list of installed measurement equipment, energy supply and data logger.

2. Requirement specifications

During the process of designing the ACWA-MS, a long list of requirement specifications have to be met, in order to apply stations into the selected aquatic environments (Kvaglund lake and Spangsbjerg Mølle lake). In this section the reader will be introduced to requirements set both by Esbjerg municipality and the science club considering weather and climate conditions.

The station designed in this project are expected to be continuously installed in the aquatic environment for three years. During the time of installation, the stations are collecting numerous climate and water quality parameters, which are saved in a data-logger. The stations will be exposed to severe weather conditions during the time of installation, which will have a significant impact to the station design. Requirements to the station design related to weather conditions are dealt with in the subsequent section.

2.1 Specifications in re. climate and weather conditions

The selected lakes, Kvaglund lake and Spangsbjerg Mølle lake are both located in Esbjerg municipality. Esbjerg is located at the geographic position 55°29′N and 08°27′E, which is in close vicinity of the North Sea. Therefore, Esbjerg has an oceanic climate, which includes high levels of humidity, salinity and precipitation. Additionally, high storm and gale activity should be expected. The air temperature is measured to 35,2°C (all time high) and to -16,6°C (all time low). This means, when designing the ACWA-MS, a maximum temperature range of close to 52°C must be considered. Material properties such as thermal expansion and glass transition temperatures of the applied materials are important factors designing the ACWA-MS.

The following list shows the requirement specifications designing the measurement stations. The station should be designed

- to withstand high wind velocities and gale (up to 35 $\frac{m}{s}$)
- to withstand cloudburst conditions (water proof installation of electric equipment)
- to withstand both extreme heat during summer and subzero temperatures during winter (choice of materials suitable for this application)
- to withstand elevated UV levels during summer month (material ageing and degradation)

Besides the requirement specifications considering specific weather and climate conditions, Esbjerg municipality also has numerous requirements to installations in aquatic environments, which are presented in the following section.

2.2 Requirement specifications from Esbjerg municipality

Kvaglund lake and Spangsbjerg Mølle lake are part of a larger surface water aquatic system within Esbjerg municipality. The network of small lakes and creaks is partially natural and partially man-made and acts as a surface water management system preventing flooding within the town of Esbjerg. The surface water passes through the system and enters the into the Wadden Sea (part of the North Sea), which is part of a natural reserve. Therefore, Esbjerg municipality has specific requirements regarding installations into this particular aquatic system, which have to be met. The measurement stations are required:

- to be non-permanent installations and leave no traceable damage to the aquatic system
- to match the surroundings and not attract attention
- not to act as resting place for birds and other animals
- not to act as place where water plants can entangle and accumulate

Besides the requirement specifications concerning weather and climate as well as Esbjerg municipality's requirements, one should also consider at the requirements concerning the stations functionality, which is presented in the following section.

2.3 Requirement specification to station functionality

The designed and constructed ACWA-MS are expected to continuously measure climate and water quality parameters over a period of 3 years. During this time frame, it is required that the stations must be self-supporting with respect to energy consumption and complying with the above stated requirements (see section 2.1 and 2.2). In this context the measurement station are required:

- to have a power supply lasting without recharging over the winter season (definition of winter season - 3 month period including November, December and January)
- to reduce power consumption as much as possible (data-logger "deep sleep" mode, no active unnecessary electrical circuits)
- to provide as high as possible sampling frequency (measuring interval of 10 - 15 minutes)
- to be autonomously recharged during time interval with sunshine (application of solar panel - 50 W module)

2.4 Requirements regarding lake bathymetry

Preliminary investigations of the lake bathymetry have shown both water depth, water flow channels and watersheds of Kvaglund lake and Spangsbjerg Mølle lake. The particular information regarding water depth and flow patterns through the lake have an strong impact on the station design. Of particular interest are the design of the stations and construction of the anchor to keep the individual station in place at the preferred location. Furthermore, mounting of sensors and application at the suitable water depth to ensure correct measurement results. The applied methods to determine water depth, calculating the bathymetry and calculating the lake bottom topography is described and presented in the first technical report No. 1, titled "Lake depth measurements (oct / nov 2020)". The report can be requested by contacting the author of this present report.

2.5 Requirement specifications overview

In order to provide an overview over all requirement specifications, this section will provide a complete table of all requirements which have to be met when designing the measurement stations. The following table 2.1 includes all requirements presented in section 2.1, 2.2 and 2.3.

Table 2.1: Overview of all requirement specifications designing and constructing the ACWA-MS. All mentioned specifications have to be met in order to ensure approval for installation from Esbjerg municipality and continuous data collection.

Category	Requirement specification
Weather and climate	- resistant to strong wind and gale - resistant to cloudburst - maintain functional within a broad temperature spectrum - resistant to elevated UV levels (during summer month)
Esbjerg municipality	- time limited installation (non-permanent approx. 3 years) - integrate into surroundings and not attracting attention - not acting as resting place for birds and other animals - not supporting accumulation or entanglement of plant material
Station functionality	- self-supporting power supply (min. 3 month solely battery driven) - reduced power consumption by deep sleep mode of data logger - aiming for high sample rate (measurement frequency each 10 to 15 min.) - recharging of battery by installed 50 W solar panel

3. Construction of station

This chapter provides insight into the construction of the ACWA-MS according to the requirement specifications introduced in chapter 2. A complete presentation of equipment installed on the stations is provided. This includes power supply, data logger and sensors. The final station setup will be illustrated together with the preferred location in the aquatic environment (Kvaglund lake and Spangsbjerg Mølle lake).

3.1 Station design

During a long and thorough process from January to April 2021, numerous suggestions of station designs, referring to the stated requirement specifications (see chapter 2), were discussed. The most preferable design resulting from the discussions, is a floating station anchored at a suitable location in each lake. Hence, the station needs a sturdy frame as well as floating bodys to provide the necessary buoyancy keeping the station afloat. The final design of the automatic climate and water monitoring station is presented in figure 3.1 and 3.2 as technical drawings. Based on the technical drawing

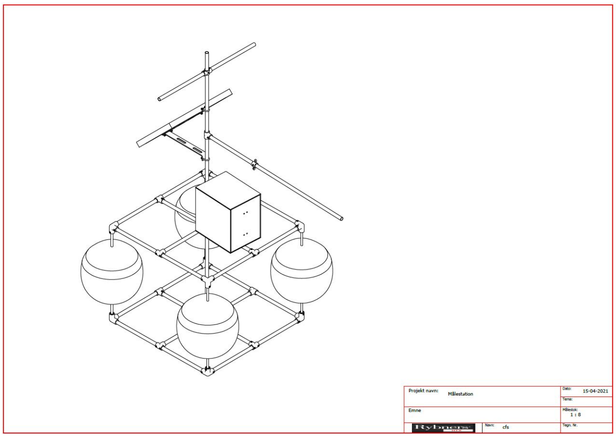

Figure 3.1: 3D technical drawing of automatic climate and water monitoring design.

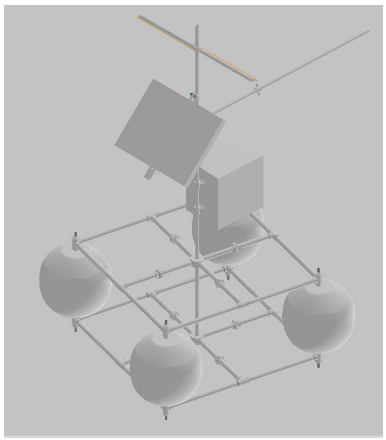

Figure 3.2: 3D model drawing of automatic climate and water monitoring station.

in figure 3.1 and 3.2, a list of the individual parts to assemble the station frame with floating bodies was completed and all parts were ordered.

The following section provides details regarding the station frame construction.

3.2 Station frame construction

The station frame as shown in figure 3.1 was constructed using "*off-the-shelf*" galvanised, 1 inch (2,54 cm) steel water piping. The raw piping was cut in adequate length according to the technical drawings shown in figure 3.3 and 3.4. Each pipe piece was finalised by cutting threading at each end. To ensure problem free assembly of the frame as well as to allow for adjustments, the threading at each pipe end was cut 50 mm. The individual pipes are joined together using standard fittings and pipe unions. Each top and bottom frame has a centre cube providing additional stability and a mounting place for the vertical centre mast. The individual frame (top or bottom) is shown in figure 3.5. Each frame consists of 4 corner fittings, 4 T-fittings, 6 pipe unions and a centre cube. Each station frame consists of a top frame and a bottom frame, which are fitted in approximately 80 cm vertical space using at each corner a thread bar. To each thread bar a floating body is mounted, placed between upper and lower frame. The floating body's are mooring buoys of the type PE M75 from Danfender (dan hill

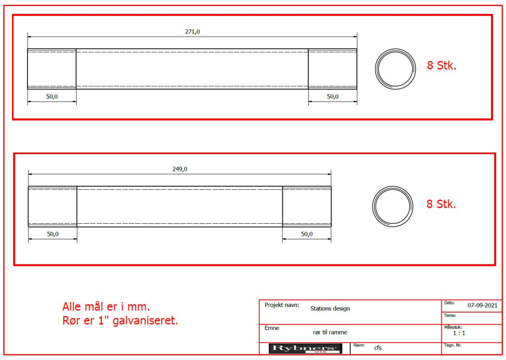

Figure 3.3: Piping pieces for station frame construction.

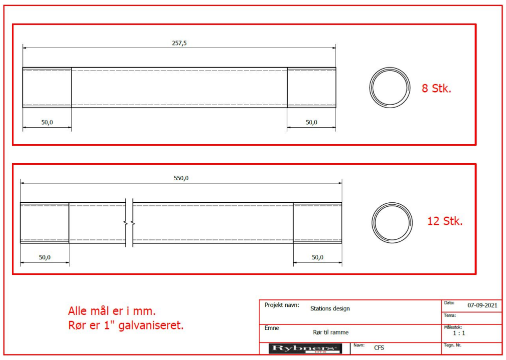

Figure 3.4: Piping pieces for station frame construction.

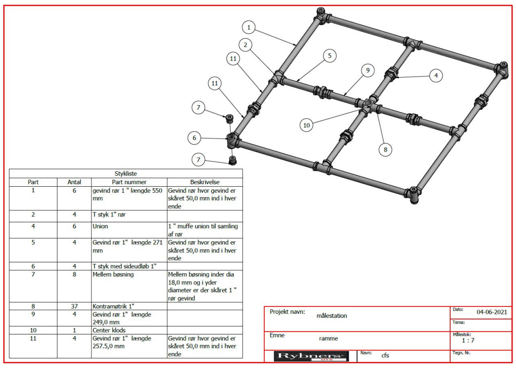

Figure 3.5: Technical drawing of upper or lower station frame

plast A/S) specially produced in a blue colour [1]. Finally, a centre mast is fitted with lock nuts in to the bottom frame centre cube and fixation clamps to the top frame centre cube.

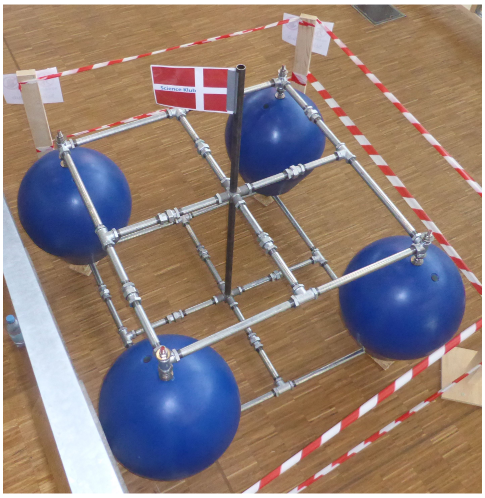

Figure 3.6: Final station framework construction and ready for assembly of equipment.

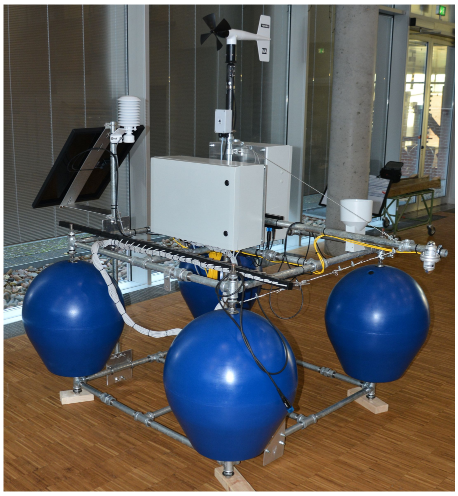

Figure 3.7: Final station with installed equipment ready to be installed in aquatic environment.

The station framework is shown in figure 3.6 and ready for assembly of power supply, data logger and measurement equipment and sensors, which will be described in the following sections 3.3, 3.4 and 3.5. The final station ready for application in the lakes is illustrated in figure 3.7.

[1]One should be aware of that the provided dimensions and hence the buoyancy stated on the companies web-page and catalogue are not correct. It turned out that the actual buoyancy of the "hard PE foam filled buoys" are 20 to 25% lower than stated, due to the applied production process, which was subject to errors.

3.3 Setup of power supply

The previous chapter 2 and sections 3.1 and 3.2 provide insight into all requirement specifications and based on those, the specific design and construction of the stations framework. This section provides information about the power supply of the stations.

The ACWA-MS are mainly powered by a 12 V, 100 Ah sealed lead acid battery (FIAMM 12FGL100). This implies that each station battery is maintenance free. Because the battery is sealed, a hazard free application for

Figure 3.8: Watertight battery box containing the battery and charge regulator.

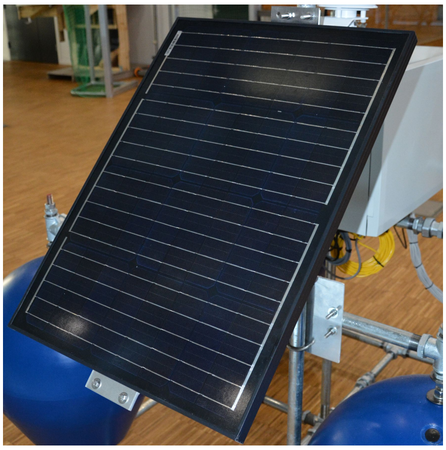

Figure 3.9: 60 W solar panel mounted to the station framework.

the surrounding aquatic environment is ensured. Extensive continuous measurements of the stations power consumption were performed, using settings closely related to operating in the aquatic environment. These measurements indicate, that the station can be solely powered by battery for approx. 7 month without other power supply. Data from the power consumption are presented in appendix A.

The battery is placed in a watertight box mounted to the centre mast, to protect it from precipitation and other environmental influences to enhance battery lifetime.

The scope of this project is to collect continuous climate and water chemistry data over a fixed time period of 3 years, which means an additional power supply is

Figure 3.10: Charge regulator ensuring that the battery is recharged when ever sufficient sunlight is available and preventing the battery from overcharging.

needed. For this purpose a 60 W solar panel is mounted to the station frame. The solar panel is mounted in an 45° angle with the horizontal plane. As the station will be freely floating around the anchor position, the solar panel cannot be optimised with respect to perfect alignment with incoming solar radiation. In the summer period, with extended sunshine hours, the solar panel will be able to fully charge the battery ensuring the continuos measurements during the time of installation. The charging process of the battery is controlled by a charge regulator, securing that the battery is recharged whenever adequate sunlight is available and preventing overcharging of the battery. The charge regulator is mounted in the watertight box, together with the battery. To illustrate the setup of the stations power supply figure 3.8 shows the battery and charge regulator installed in a watertight box. The installation of the solar panel is shown in figure 3.9.

3.4 Setup of data collection

The measurement intervals, data collection and data storage are controlled by the installed data logger. The data logger and all the instruments are powered by the in section 3.3 described power supply. Each station is equipped with a data logger model DataTaker DT85 and a channel expansion module (CEM 20). The data logger DT85 is programmed in such a way, that each 10 or 15 minutes a measurement of all parameters is taken, by activating all attached sensors. An overview of all sensors and parameters is providet in section 3.5. To illustrate the data logger setup and the CEM20 see figure 3.11 and 3.12. The collection of all measurements takes

Figure 3.11: Data logger DataTaker DT85.

Figure 3.12: Channel extension module CEM20.

approximately 40 seconds. The remaining time, where no measurements are acquired, the data logger switches into a sleep mode (including the CEM 20 module and all other circuits). The energy consumption during the sleep mode is approximately 22 mW (1,8 mA). During the active time of the data logger and channel extension module the power consumption raises to an measured average value of 4,2 W (350 mA). However, during measurements peak currencies of 1 A where observed. For more information regarding the power consumption see also appendix A.

Figure 3.13: Data logger DT85 and channel extension module CEM20 installation in data logger box. All cables connected to the data logger and CEM20 module passing through water tight fittings in the bottom of the data logger box to the individual sensor.

Figure 3.14: Data logger DT85 and channel extension module CEM20 setup in watertight box from a different angle.

A watertight box is applied to contain and protect the data logger and the channel extension module from weather, precipitation and condensation (see figure 3.13 and 3.14). The cables connecting the data logger and the sensors are passing through water tight fittings in the bottom of the data logger box, to ensure that the data logger and the CEM20 module are not exposed to elevated moisture levels.

3.5 Measurement equipment

This section provides an overview over all installed sensors and hence, the measured parameters of each individual station. It is important to notice, that there are 3 stations assembled within the project. All 3 stations are

Table 3.1: Equipment installed to each automatic climate and water monitoring station.

Sensor / parameter	Kvaglund lake[1]	Sp. Mølle lake[2]	Rybners HTX[3]
Wind speed	X	X	X
Wind direction	X	X	X
Compass	X	X	
Humidity	X	X	X
Temperature	X	X	X
Rain gauge	X	X	X
Barometer	X	X	X
Temperature profile of water column (24 PT100)	X	X	
Albedometer	X		
Aquaread 7000 probe	X		
Aquaread 5000 probe		X	X
Ammonium sensor	X	X	X
Nitrate sensor	X	X	X
Chlorophyll sensor	X		
Turbidity sensor	X	X	X
Conductivity sensor	X	X	X
pH sensor	X	X	X

[1] - Station monitoring Kvaglund lake
[2] - Station monitoring Spangsbjerg Mølle lake
[3] - Station remaining at Rybners HTX as demonstration station, to experiment and learn about its functions.

individual equipped with sensors and therefore, the parameters measured vary from each location. It is also important to notice that the third station, which remains at Rybners HTX, does not collect any measurements but should be thought of as a demonstration and trainings station. Table 3.1 provides an overview over the installed sensors to each station.

The following subsections provide insight into the applied climate sensors (se subsection 3.5.1) and the applied water quality sensors (see subsection 3.5.3).

3.5.1 Climate sensors

This subsection introduces all sensors installed to the ACWA-MS. Specific information such as measurement range, accuracy, dimensions, weight *etc.* are provided. To illustrate the design and construction, a photograph of each applied sensor is presented in a figure.

Wind direction and wind speed

Wind direction and wind speed is measured applying a Young Wind Monitor - MA model 05106 as shown in figure 3.15. MA indicates that this model is a marine model, specific developed for marine applications. Marine applications can be vessels, leisure boats or other free floating applications such as the here presented ACWA-MS. In these cases the wind monitor requires an additional compass in order to provide a reference direction (absolute north), to determine the correct wind direction. The applied compass (model 32500) is shown in figure 3.16.

Figure 3.15: Wind speed and wind direction measurement sensor Young Wind Monitor - MA (model 05106).

Figure 3.16: Young compass (model 32500) to determine reference north for calculating correct wind direction.

The compass is mounted on the stations centre pipe (see figure 3.6). The Young Wind Monitor is mounted on top of the centre pipe, ensuring the wind direction sensor can rotate 360° and is not influenced by wind shadow from other installations to the station.

The Young Wind Monitor - MA 05106 has the following specifications shown in table 3.2.

Table 3.2: Specifications of Young Wind Monitor - MA 05106.

Specification	Value
Wind speed (Range)	0 - 100 $\frac{m}{s}$
Wind speed (Accuracy)	± 0,3 $\frac{m}{s}$
Wind speed (Threshold propeller)	1,1 $\frac{m}{s}$
Wind Speed (Threshold vane)	1,1 $\frac{m}{s}$
Wind direction (Range)	360°
Wind direction (Accuracy)	± 3°
Dimensions:	
Height	37 cm
Length	55 cm
Propeller diameter	18 cm
Mounting (diameter)	34 mm (1 inch standard pipe)
Weight	1 kg

Air temperature and humidity

Air temperature and humidity are measured using a Young relative humidity and temperature probe Model 41382LC2. The combined air temperature and humidity sensor is shown in figure 3.17.

The actual sensor is placed behind the cover (white lamella cover) in order to protect the sensor from direct exposure to precipitation, wind and solar radiation. The relative humidity and temperature probe has the following specifications shown in table 3.3. The temperature sensor is a platinum resistance temperature detector (RTD) with a high accuracy. The Young relative humidity and temperature probe Model 41382LC2 applies a Rotronic hygrometer sensor.

Figure 3.17: Air temperature ans humidity measurement sensor.

Table 3.3: Specifications of Young relative humidity and temperature probe model 41382LC2.

Specification	Value
Relative humidity (Range)	0 - 100%
Relative humidity at 23°C (Accuracy)	± 1%
Temperature (Range)	-50 to 50°C
Temperature at 23° (Accuracy)	± 0.3°C
Dimensions:	
Height (of probe)	17,7 cm
Diameter (of probe)	6,2 cm

Atmospheric pressure

The atmospheric pressure is measured using a Young barometric pressure sensor model 61302L. The sensor is designed allowing high accurate pressure measurements over a wide temperature range. Furthermore, the sensor is maintenance free and requires occasional recalibration. The pressure sensor is mounted (on the station), inside the data logger box, to protect it from precipitation and other harsh weather conditions. In order to measure the correct atmospheric pressure without disturbance, a flexible tube is connected to the pressure sensor terminating with the open end outside at the bottom of the data logger box. The specifications of the pressure sensor Young barometric pressure model 61302L are presented in table 3.4.

Figure 3.18: Atmospheric pressure measurement sensor - barometer.

Table 3.4: Specifications of Young barometric pressure sensor model 61302L.

Specification	Value
Pressure (Range)	500 - 1100 hPa
Pressure (Accuracy)	± 0,2 hPa (25°C)
	±0,3 hPa (-50°C to +60°C)
Dimensions	
Height	4 cm
Brede	6 cm
Depth	3 cm
Weight	44 g

Precipitation

Precipitation is measures using a PRONAMIC Rain-O-Matic professional rain gauge. The sensor is specifically designed to measure precipitation

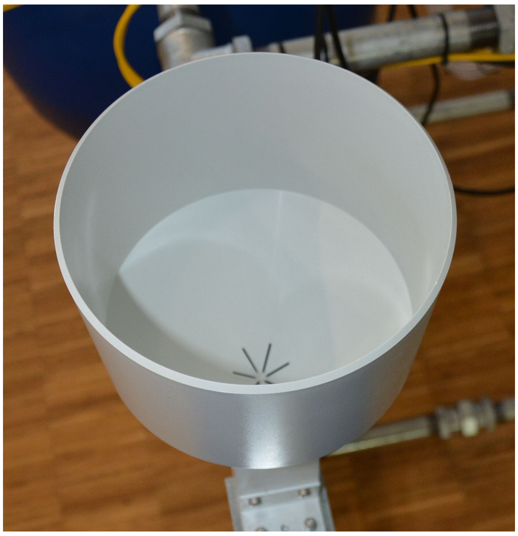

Figure 3.19: Rain gauge catchment.

Figure 3.20: Rain gauge sensor to measure precipitation.

continuously with a high resolution. The sensor is designed in such a way

Table 3.5: Specifications of PRONAMIC Rain-O-Matic professional rain gauge.

Specification	Value
Read time	190 ms
Read amount (accuracy per tip)	0,2 mm per tip (emptying)
Dimensions	
Orfice (catchment surface)	200 cm^2
Height	25,5 cm
Length	10 cm
Depth	5 cm
Weight	380 g

that the catchment vessel is placed directly over the measurement bucket which is self-emptying. The bucket can empty in less than 300 ms and has a resolution of 0,2 mm precipitation. The specification of the rain gauge are presented in table 3.5.

Albedo

The albedo measurement is performed using two Kipp & Zonen SMP3 smart pyranometers. The pyranometers are mounted back-to-back, where one pyronometer points upward and one downward. Both glass domes form a perpendicular line with the horizontal plane. In that way it is possible to measure the incoming solar radiation as well as the reflected solar radiation by the lake surface. The difference of both values is the absorbed radiation (energy) by the lake water. The pyranometer sensors are sensitive to a broad range of the electro magnetic spectrum, detecting radiation within a wavelength interval between 300 to 2800 nm. The installed albedometer is illustrated in figure 3.21.

Figure 3.21: Albedometer measuring incoming and reflected solar radiation.

Table 3.6: Specifications of albedometer consisting of two back-to-back mounted SMP3 smart pyranometers from Kipp & Zonen.

Specification	Value
Energi equivalent (range)	-200 to 2000 W/m^2
Spectral range	300 to 2800 nm
Response time (63%)	< 1,5 s
Response time (95%)	< 95 s
Field of view	180°
Spectral selectivity (350 - 1500 nm)	<1%
Dimensions	
Height	8,4 cm (16,8 cm)
Diameter	11 cm
Weight	300 g (900 g)

3.5.2 Water temperature profile

The stations monitoring each lake, are equipped with a temperature array consisting of 24 PT-100 temperature sensors. The sensors are equally distributed with a 5 cm spacing and connected to the CEM20 using all 20 channels and the remaining 4 sensors are connected to the data logger DT85 directly. The temperature array is mounted to the station frame in that way, that all temperature sensors are submerged. Furthermore, the sensor array is perpendicular in relation to the water surface. It is therefore possible to determine the development and change of the vertical temperature profile in the water column over time. Especially, the correlation between forming of a distinct temperature profile during the winter and summer stagnation related to the surrounding weather conditions is of interest.

Figure 3.22: Temperature array measurement using 24 PT-100 sensors with an equidistant 5 cm spacing to measure the vertical temperature profile in each lake.

3.5.3 Water quality measurements

The water quality is monitored using an Aquaread probe AP-7000 applied to the station placed in Kvaglund lake and a Aquaread probe AP-5000 applied to the station placed in Spangsbjerg Mølle lake. The subsequent sections provide an overview over the parameters measured by each probe as well as the accuracy of the measurement.

AP - 7000 Aquaread probe

Figure 3.23: Aquaread probe AP-7000 with protective cover to protect the sensors and electrodes.

The entire Aquaread AP-7000 probe is shown in figure 3.23. At the top of the probe in figure 3.23, the probe has a connector for the data transmission cable as well as threading for mounting the aluminium holder to attach a steel wire, holding the probe in the right water depth. The upper part of the probe (from the blue ring upwards) contains the electronics as well as all the connector for the individual electrodes and sensors. The lower part of the probe (from the blue ring downwards) is the metal cover protecting the electrodes and sensors. The electrodes and sensors are mounted circular around the centre holder. Furthermore, the Aquaread AP-7000 probe has a self-cleaning mechanism, where a brush rotates before each measurement cleaning all electrodes and optical sensors for fine particulates and other impurities. All electrodes and sensors are calibrated according to the procedures describes in the AP-7000 manual. The Aquaread AP-7000 probe is connected via a specific cable to the Aquaread Black Box, which is a data converter (se figure 3.29). The Aquaread Black Box is connected to the data logger (Data Taker DT85 - see also section 3.4). The Aquaread probe with removed sensor cover is shown from different angles in figure 3.24 and 3.25.

All parameters measured and the accuracy of the respective sensor are provided in table 3.9. The Aquaread AP-7000 probe is equipped with a set of

Figure 3.24: Individual optical sensors and electrodes mounted to the Aquaread AP-7000 probe.

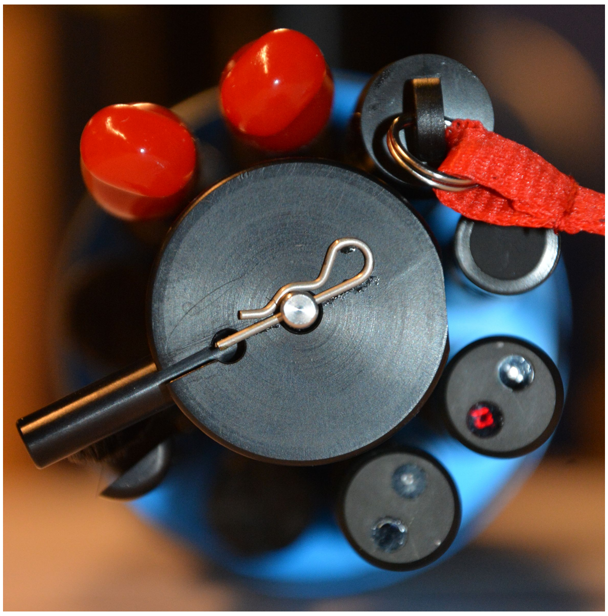

Figure 3.25: Bottom view on mounted optical sensors and electrodes as well as cleaning brush.

standard electrodes as well as up to 6 optional sensors (ISE or optical). The AP-7000 probe applied to Kvaglund lake measures the following parameters:

- Standard parameter: optical dissolved oxygen, specific electric conductivity, absolute electric conductivity, pH, oxidation reduction potential (ORP), total dissolved solids (TDS), resistivity, salinity, depth and water temperature (at depth of sonde)
- Optional parameter: ammonium, ammonia, nitrate, turbidity and chlorophyll

Table 3.7: Specifications of Aquaread AP-7000 probe.

Specification	Value
Immersion depth	min.: 150 mm; max.: 100 m
Operating temperature	- 5°C to +50°C
Dimensions	
Length	450 mm
Diameter	77 mm
Weight	1350 g

AP - 5000 Aquaread probe

The entire Aquaread AP-5000 probe with the aluminium extension, to attach the probe to the station using a steel wire, is shown in figure 3.26. At the top of the sonde a connector is placed, attaching the data transmission cable as well as threading for mounting the aluminium cable holder. The upper part of the probe (from the blue ring upwards) contains the electronics as well as all the connector for the individual electrodes and sensors. The lower part of the probe (from the blue ring downwards) is the metal cover protecting the electrodes and sensors. The electrodes and sensors are mounted circular. The AP-5000 probe compared to the AP-7000 probe does not have a motorised brush for self-cleaning. All electrodes and sensors are calibrated according to the procedures describes in the AP-5000 manual. The Aquaread AP-5000 probe is connected via a specific cable to the Aquaread Black Box, which is a data converter (se figure 3.29). The Aquaread Black Box is connected to the data logger (Data Taker DT85 - see also section 3.4). The technical data and dimensions of the Aquared AP-5000 probe are listed in table 3.8. All parameters measured and the accuracy of the respective sensor are provided in table 3.9.

Figure 3.26: Aquaread probe AP-5000 with protective cover to protect the sensors and electrodes.

The Aquaread AP-5000 probe with removed sensor cover is shown from different angles in figure 3.27 and 3.28. The Aquaread AP-5000 probe is equipped with a set of standard electrodes as well as up to 4 optional sensors (ISE or optical). The AP-5000 probe applied to Spangsbjerg Mølle lake measures the following

Figure 3.27: Individual optical sensors and electrodes mounted to the Aquaread AP-5000 probe.

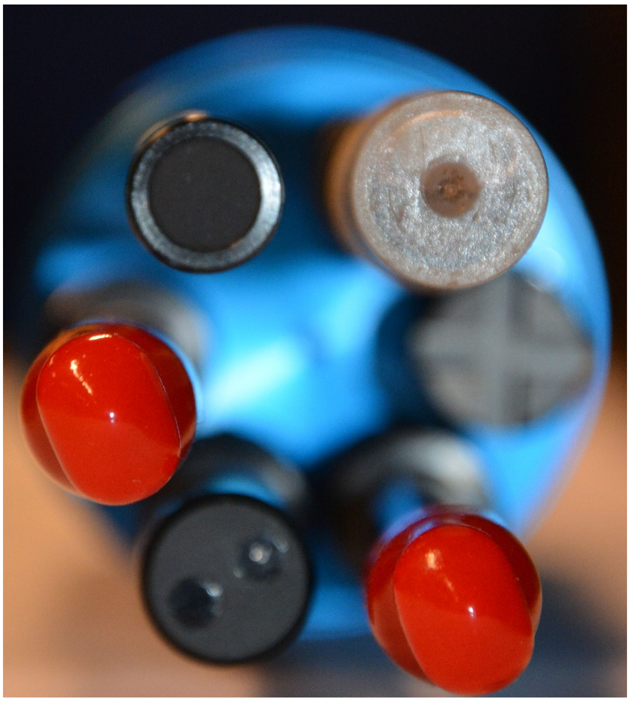

Figure 3.28: Bottom view on mounted optical sensors and electrodes.

parameters:

- Standard parameter: optical dissolved oxygen, specific electric conductivity, absolute electric conductivity, pH, oxidation reduction potential (ORP), total dissolved solids (TDS), resistivity, salinity, depth and water temperature (at depth of sonde)
- Optional parameter: ammonium, ammonia, nitrate, turbidity

Table 3.8: Specifications of Aquaread AP-5000 probe.

Specification	Value
Immersion depth	min.: 75 mm; max.: 100 m
Operating temperature	- 5°C to +70°C
Dimensions	
Length	340 mm
Diameter	55 mm
Weight	950 g

Figure 3.29: Aquaread black box connecting the aquaread probe (AP-7000 / AP-5000) to the datalogger DT85. The aquaread black box acts as signal converter, making the signal readable for the datalogger.

Table 3.9: Electrode specifications of Aquaread AP-7000 and AP-5000 probe.

Specification	Range	Resolution	Accuracy
Optical dissolved oxygen	0 - 50 $\frac{mg}{l}$	0,01 $\frac{mg}{l}$	± 1%
Specific /absolute electric conductivity	0 - 200 $\frac{mS}{cm}$	0 - 9999 $\frac{\mu S}{cm}$ 10,00- 99,99 $\frac{mS}{cm}$ 100,0 - 200,0 $\frac{mS}{cm}$	± 1 $\frac{\mu S}{cm}$
pH	0 - 14 pH	0,01 pH	± 0,01 pH
Oxidation reduction potential	± 2000 mV	0,1 mV	± 5 mV
Total dissolved solids	0 - 10^6 $\frac{mg}{l}$	0 - 9999 / $\frac{mg}{l}$ 10,00 - 100,00 $\frac{g}{l}$	± 1%
Resistivity	5 - 10^6 $\frac{\Omega}{cm}$	5 - 9999 $\frac{\Omega}{cm}$ 510,0 - 1000,0 $\frac{k\Omega}{cm}$	
Salinity	0 - 70 $\frac{g}{kg}$	0,01 ppt	± 1%
Temperature	-5 - +50°C	0,1°C	±0,5°C
Ammonium & ammonia	0 - 1000 $\frac{mg}{l}$	0,00 - 99,99 $\frac{mg}{l}$ 100,0 - 999,9 $\frac{mg}{l}$	± 10%
Nitrate	0 - 1000 $\frac{mg}{l}$	0,00 - 99,99 $\frac{mg}{l}$ 100,0 - 999,9 $\frac{mg}{l}$	± 10%
Turbidity	0 - 3000 NTU	0,0 - 99,9 NTU 100 - 3000 NTU	± 2%
Chlorophyll	0 - 500 $\frac{\mu g}{l}$	0,1 $\frac{\mu g}{l}$	± 2%

4. AKVA-MS installation in lake

4.1 Lake locations

The previously described design and construction of the ACWA-MS are expected to be installed in lakes within Esbjerg municipality. The two lake locations are Kvaglund lake and Spangsbjerg Mølle lake (see figure 1.1). The lakes were chosen as they are part of a larger aquatic network transporting surface water towards the Wadden Sea and North Sea (national park Wadden Sea). Additionally, both lakes are connected with each other by Spangsbjerg Mølle creak, which allows tracing the concentration of possible pollutants from one lake to another. Furthermore, both lakes are in close vicinity of Rybners HTX and hence easy accessible for frequent visits, station maintenance and data collection. Figure 1.1 provides an overview over the area of interest.

4.1.1 Location Kvaglund lake

The ACWA-MS to be installed in Kvaglund lake is equipped with numerous sensors and data collecting equipment as described in section 3.5. The par-

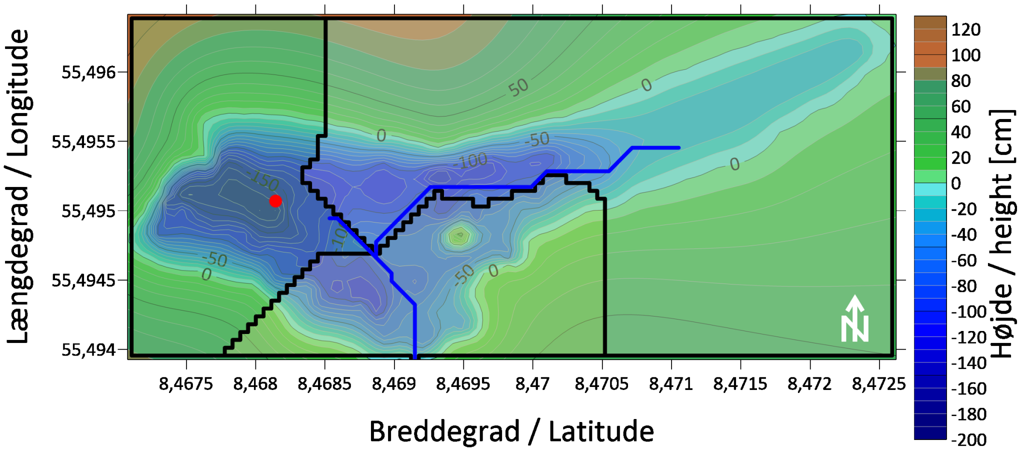

Figure 4.1: Determined watershed of Kvaglund lake from bathymetry assessment. The red dot indicates the location where the automatic climate and water monitoring station will be installed.

ticular location in the lake where the station will be installed is determined by the preliminary assessment of the lake bathymetry described in technical report No. 1 of this project, titled Lake depth measurements (oct / nov

2020). The report can be requested by contacting the author of this present report

Based on the bathymetry of Kvaglund lake and identifying the lakes catchment areas, the specific location of the monitoring station is determined. The location is shown in figure 4.1, indicated by the red dot. The location is chosen because of the lake depth and as close as possible to the overall water flow through the lake. The geographic location of the ACWA-

Table 4.1: GPS coordinates of station location for Kvaglund lake, based on the preliminary assessment of water depth measurements and bathymetry. The values are provided in the World Geodetic System 84 (WGS 84).

GPS coordinate format	Latitude	Longitude
Degrees Minutes Seconds (DMS)	55° 29' 42,12" N	8° 28' 5,69" E
Decimal Degrees (DD)	55,4950327	8,4682472

MS placed in Kvaglund lake is provided in table 4.1. The coordinates of the location are provided in the degree minute seconds (DMS) format and in the decimal degree (DD) formate. Both geographic locations are referenced to the World Geodetic System 84 (WGS 84) ellipsoid in order to match the coordinates of the watershed map.

4.1.2 Location Spangsbjerg Mølle lake

Analogue to placement of the ACWA-MS in Kvaglund lake, the same method is applied to determine the preferred location for the ACWA-MS in Spangsbjerg Mølle lake. The ACWA-MS to be installed in Spangsbjerg

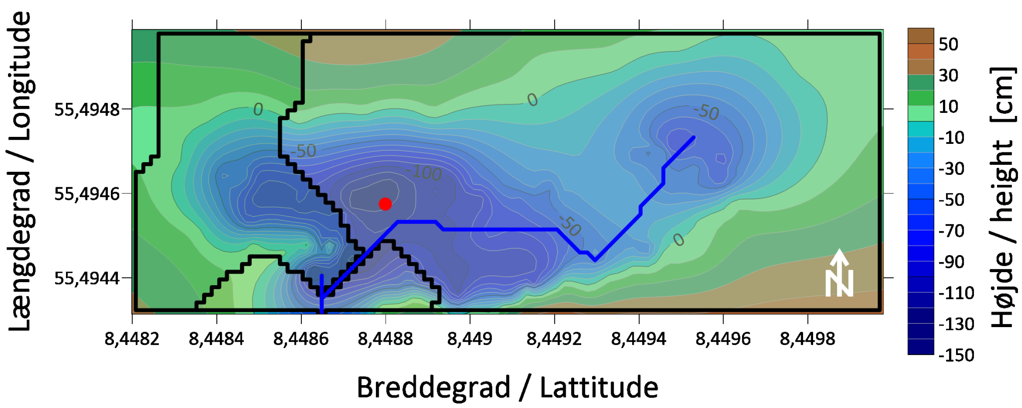

Figure 4.2: Determined watershed of Spangsbjerg Mølle lake from bathymetry assessment. The red dot indicates the location where the automatic climate and water monitoring station will be installed.

Mølle lake is equipped with numerous sensors and data collecting equipment as described in section 3.5. Based on the bathymetry of Spangsbjerg Mølle lake and identifying the lakes catchment areas, the specific location of the monitoring station is determined. The location is shown in figure 4.1 indicated by the red dot. The location is chosen with respect to lake depth and as close as possible to the overall water flow through the lake. The

Table 4.2: GPS coordinates of station location for Spangsbjerg Mølle lake, based on the preliminary assessment of water depth measurements and bathymetry. The values are provided in the World Geodetic System 84 (WGS 84).

GPS coordinate format	Latitude	Longitude
Degrees Minutes Seconds (DMS)	55° 29’ 40,02” N	8° 26’ 55,94” E
Decimal Degrees (DD)	55,4945062	8,4488715

geographic position of the ACWA-MS placed in Spangsbjerg Mølle lake is provided in table 4.2 is provided in the degree minute seconds (DMS) format and in the decimal degree (DD) format. Both geographic positions are referenced to the World Geodetic System 84 (WGS 84) ellipsoid in order to match the coordinates of the watershed map.

5. Conclusive remarks

5.1 Stations

Chapter 2 provided insight into the requirements the ACWA-MS must fulfil in order to ensure continuous and accurate function. The previous chapter 3 introduced the reader to the general process, constructing the automatic climate and water monitoring stations. Furthermore, a detailed introduction of each applied sensor is provided. The final assembled station ready for installation in Kvaglund lake and Spangsbjerg Mølle lake is shown in figure 5.1 and 5.2. The choice of the specific location af each station in the

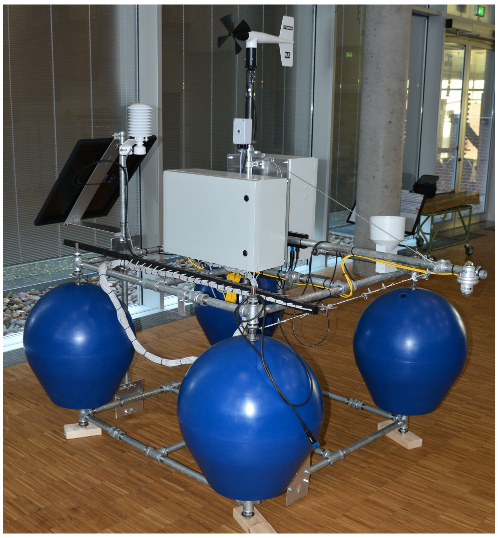

Figure 5.1: Assembled automatic climate and water monitoring station ready for application in Kvaglund lake.

Figure 5.2: Assembled automatic climate and water monitoring station ready for application in Kvaglund lake - different angle.

lakes is presented in chapter 4.

5.2 Further work

The assembled stations will be installed to Kvaglund lake and Spangsbjerg Mølle lake, respectively as soon as weather conditions are suitable for safe fieldwork. The stations are expected to work and collect data continuously for 3 years after installation. The collected data material will be used for scientific analysis and insight into annual fresh-water environment behaviour in urban areas as well as used for practical examples and courses in lower and higher education.

A. Appendix - Measurement of energy consumption

After the ACWA-MS stations were assembled, measurements of the energy consumption are performed. The results of these measurements are presented in this appendix. The stations power supply, the FIAMM 12GL100 battery was fist fully charged before running the test measurements. Furthermore, the solar panel was covered using a cardboard sheet in order to investigate the the energy consumption solely using battery power. The measurement interval, taking a reading of all sensors, was set to 10 minutes.

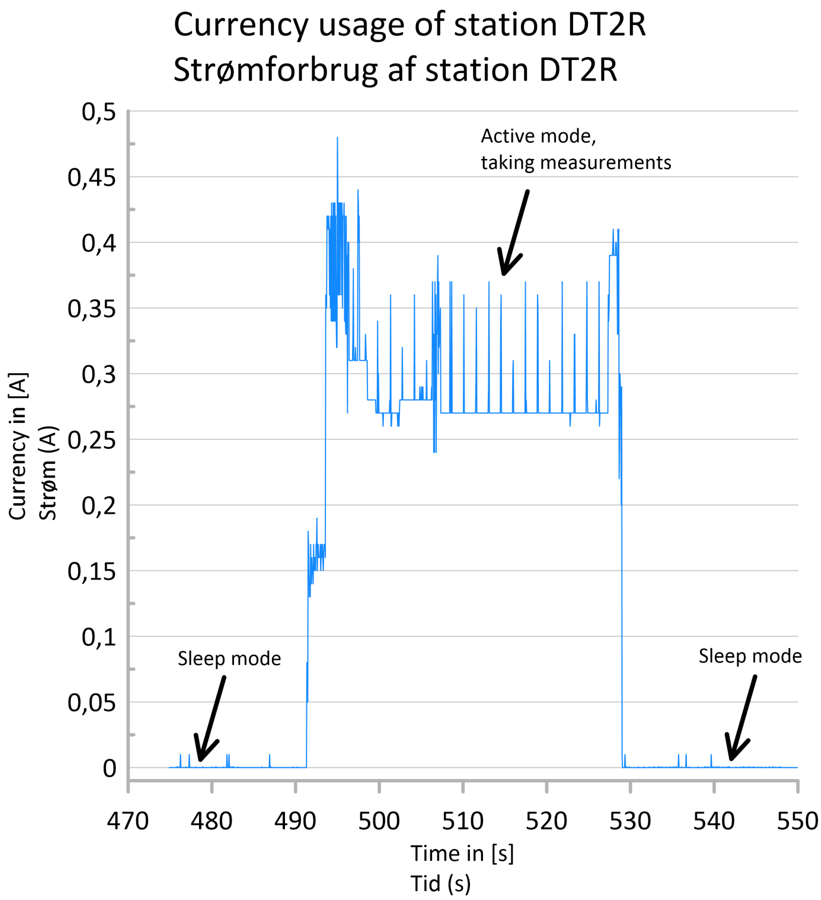

Figure A.1: Currency measurement for a singe active mode. The data logger is activated and taking readings of all sensors both connected to the data logger directly and from the CEM20 channel extension module. The remaining currency measurements indicate the sleep mode of the data logger, reducing the energy consumption to a minimum.

During the readings, full power consumption is expected. The time interval between each measurement, the data logger returns in a sleep mode, shutting down all circuits and reducing power consumption to a minimum. The measurement results of the currency usage is shown in figure A.1 and A.2.

Figure A.1 illustrates clearly the difference between sleep mode and the time interval taken the measurements (active period). The measurements were performed over a 7 days with a sampling frequency of 20 Hz (20 currency measurements each second). Extracting all the active interval from the dataset, it showed that the average currency during the active period is approx. 0,35 A for ca. 37 seconds. During the sleep phase of the system, the average currency was determined to 0,00187 A for ca. 563 seconds. To

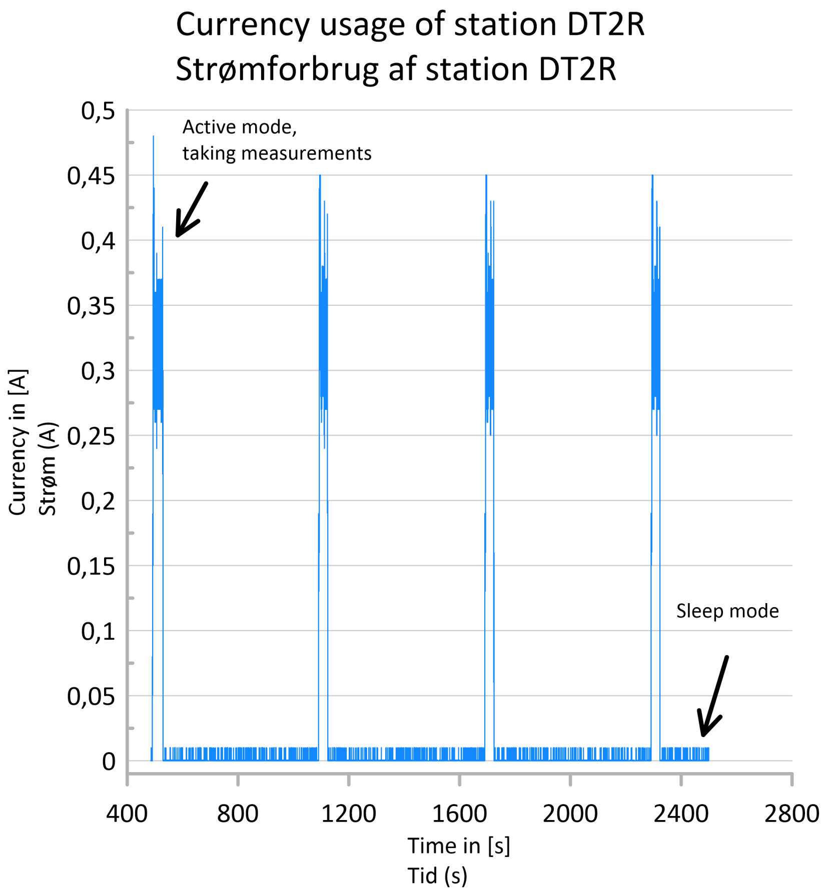

Figure A.2: Currency measurement showing 4 active modes and intermediate sleep modes.

get a better understanding of the transition between sleep and active stage of the system figure A.2 illustrates four active intervals and the intermediate sleep intervals. Important to notice is, that the measurements were performed solely using battery power. The installed solar panels did not contribute to the energy supply. In this particular pattern measures the station continuously all parameters according to the installed sensors (see table 3.1).

Figure A.3 shows the battery voltage during time, running the stations data logger solely on battery power. The battery was fully charged to 13.11

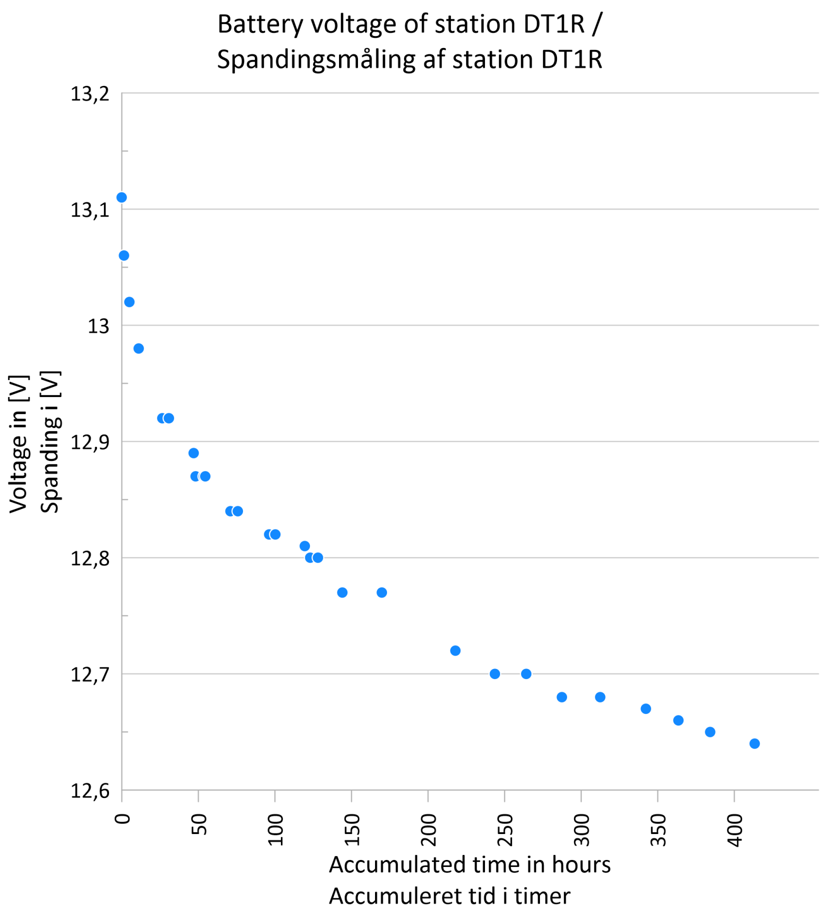

Figure A.3: Measurement of battery voltage during time, when the station is running solely on battery power.

V. The significant drop of voltage in the beginning of the measurement is common for lead acid batteries. However, the voltage stabilises after approx. 200 hours and decreases with less than 0,01 V per day. Hence, the station in this mode is self-supporting for more than 3 month, which was on important requirement regarding the station design (see section 2.3).