UN Environment GEMS/Water Capacity Development Centre

Training Workshop Report
Monitoring Programme and Network Design for Surface Water Bodies
Senegal, 2 – 4 July 2018

University College Cork, Ireland
Coláiste na hOllscoile Corcaigh
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1 INTRODUCTION

The UN Environment GEMS/Water programme ran a training workshop in Dakar, Senegal in July 2018. The workshop was the first training workshop delivered by the GEMS/Water Capacity Development Centre to Francophone countries in Africa using simultaneous English/French translation.

This training workshop is part of a series to address capacity deficits relating to monitoring and assessment of water quality in rivers, lakes and groundwaters that were identified during a global scoping exercise. Without appropriate and adequate water quality data, management decisions may be lacking or incomplete, leading to detrimental effects on human and ecosystem health, and the economic status of a country. Developing capacity by training personnel in countries in Africa reduces one of the barriers to generating water quality information, and raises the awareness of the importance of good water quality in support of sustainable development of natural water resources and of the goals of Agenda 2030.

This training workshop focussed on monitoring programme and network design for surface waters. This topic is fundamental in the monitoring and assessment process, and provides the foundation for effective management of freshwater resources. This step is essential for the generation of sound, scientifically robust data that can be used to support good decisions. This workshop provided participants with the necessary knowledge to help them complete the design process from setting objectives, planning the sampling network and field and laboratory activities, through to programme review.

Each of the three GEMS/Water Centres: the Global Programme Coordination Unit (GPCU); the Data Centre (DC); and the Capacity Development Centre (CDC) contributed to organisation and delivery of the workshop, with the GPCU taking the lead on organisation, and the CDC the lead on workshop content development and delivery. The workshop was held over three days and was attended by 14 participants from 13 countries (Figure 1). The structure followed a similar workshop delivered in Nairobi to Anglophone African countries in December 2017. The format of the workshop was divided between lectures delivered by the presenters from GEMS/Water, and group-work to focus on key learning outcomes. All participants had technical backgrounds, and were either actively involved in water quality monitoring, and attended to improve or extend their

Figure 1: Workshop participant countries

monitoring activities, or their country was in the early stages of designing national surface water quality monitoring programmes.

2 WORKSHOP DAY 1

The workshop started with the official welcome from Mr Niokhor Ndour of the host country representing the Directorate of Management and Planning of Water Resources (Direction de la Gestion et de la Planification des Ressources en Eau - DGPRE), of the Ministry of Hydraulics and Sanitation (Ministère de l'Hydraulique et de l'Assainissement). A brief overview of GEMS/Water's structure and mission was provided by Deborah Chapman, the Director of the CDC, which was followed by introductions from all participants, who were given the opportunity to describe the water quality monitoring activities in their own country. The remainder of the day was divided between the delivery of lecture content and group exercises to lay the foundation for days two and three. The day concluded with a food and drinks reception.

Figure 2: Participants engaging in group sessions and presenting their group's work

2.1 NATIONAL MONITORING PROGRAMME DISCUSSION

Each participant was offered the opportunity to summarise the state of surface water monitoring programmes in their own countries, and to discuss the limitations and points of interest. Some key comments are summarised below:

- *Monitoring activities are inconsistent, depending on available finances, and therefore there are many gaps in the data record.*
- *The opportunities to attend these types of training workshops are limited.*
- *Currently, we do not have a water quality laboratory available.*
- *There is a need to assess the impact from agricultural non-point sources of pollution, which is currently not possible with the existing monitoring network.*
- *The costs of reagents and therefore analysing water quality are very high, and the funds are often difficult to justify to management.*
- *The need to expand monitoring activities is understood, but progress is very slow with the finances available.*

- *Monitoring is underway but quality assurance is an issue for some laboratories, and capacity development in this area is needed.*
- *Engaging with the SDGs (indicator 6.3.2 on ambient water quality) has driven the expansion of monitoring activities, with additional parameters being analysed and more monitoring locations being sampled.*

2.2 MONITORING FOR INFORMATION AND MANAGEMENT

This session provided background information on water quality, describing the basics of monitoring and why it is necessary. The role of water quality monitoring in water management was outlined and the considerations for designing a successful monitoring programme were covered. The links between intended uses of the water, and how this determines the choice of monitoring method was described, and finally the benefits of monitoring programmes and the types of questions that can be answered by a well-designed programme were detailed.

In Summary:

- The quality of freshwater bodies is under threat from domestic, agricultural and industrial activities.
- Monitoring programmes are essential for:
  - environmental protection by tracking and controlling the impacts of human activities;
  - the selection and development of management options; and
  - policy formulation.
- Monitoring data need to be accessible in order to be useful for management and policy development. They need to be assessed and communicated as information and should not remain in data stores.
- The success of a monitoring programme is dependent on having clearly defined objectives which will support a cost-effective monitoring programme designed in relation to the personnel and resources available.

Figure 3: Participants discussing their scenario and presenting their results

2.3 UNDERSTANDING YOUR WATERBODY: ECOLOGY AND HYDROLOGY

This session focussed on the importance of understanding natural influences on an aquatic system, and how this leads to better monitoring programme design and interpretation of monitoring results. Geographical location, climate and geology affect the water quality of rivers and lakes, and understanding how these can influence the ecological and hydrological nature of the aquatic system being monitored is critical for the design process. Without this understanding, vital elements of a programme may be omitted, or results may be misinterpreted. For example, the velocity of water in a river depends on the gradient, and the size and shape of the channel. Water velocity is usually higher in the headwaters and slower downstream. The velocity of river water affects: the nature of the benthic substrate; the ability of rooted plants to establish and grow; the potential for microalgae to establish high population densities; the types of benthic microorganisms that can thrive; and the ability for specific fish species to feed and spawn. This session described the benefits of how this, and additional information on the ecology and hydrology of a water body can lead to better assessment.

2.4 MONITORING AND ASSESSMENT PROCESS OVERVIEW

The steps of developing a monitoring and assessment programme were described in this session, including details of each step, and how these steps are organised into three phases: design; implementation; and assessment, reporting and management.

The essential role of the process in designing a sound and reliable monitoring programme was illustrated, with a focus on how each step relies on the previous ones. The iterative nature of the design process, and how essential it is to define the monitoring programme objectives clearly from the outset, and then to refer to them throughout the design process, was described. The steps are illustrated in Figure 4 below.

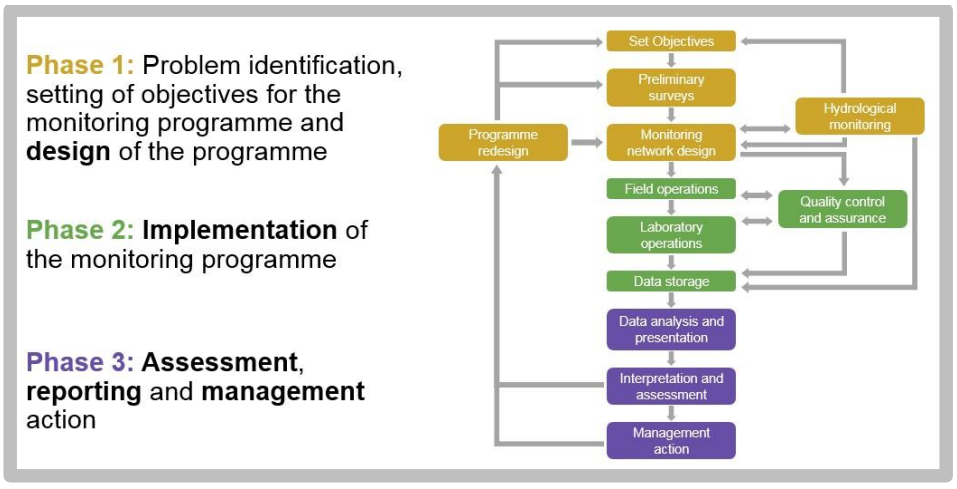

Figure 4: Monitoring and assessment process flowchart (adapted from (Chapman *et al.*, 2005)[1]

[1] Chapman, D. V, Meybeck, M. & Peters, N.E., 2005. Water Quality Monitoring. In *Encyclopedia of Hydrological Sciences*. Chichester, UK: John Wiley & Sons, Ltd. Available at: http://doi.wiley.com/10.1002/0470848944.hsa094 [Accessed January 21, 2019].

2.5 MONITORING SITE AND STATION SELECTION

Sampling location and sample collection frequency are important considerations in monitoring network design because they affect how accurately the results obtained represent the water quality of the water body. This session looked at the different factors that need to be considered when identifying sampling locations and defining the frequency of sample collection. For example, a long-term surveillance programme of water quality at an abstraction point may require sample collection at a single location on a continuous basis. In contrast, a monitoring programme to provide information on the ecosystem health of surface waters at the national level, may require very many locations, but monitored on a quarterly or seasonal frequency.

2.6 GROUP EXERCISE - SITE SELECTION

This exercise challenged participants to use their experience and the information provided during the morning to suggest suitable monitoring locations for one of three scenarios. Participants were divided into three groups of four or five with one of the participants acting as rapporteur for the group. The scenarios given to the groups were:

A. Impact of an industrial discharge in a river.
B. Ambient water quality of an international river basin discharging to the ocean.
C. Impact of an accidental spill of a toxic liquid into a river feeding into a lake.

Each of the three groups successfully identified the key monitoring locations to fulfil the objectives of each monitoring programme scenario. The rapporteurs presented the results on behalf of each group, and fielded questions and provided elaboration where needed.

Figure 5: Participants engaged in group work

3 WORKSHOP DAY 2

Day two followed the same format as day one with presentations in the morning, followed by group exercises after lunch and a discussion session at the end.

3.1 CHOOSING WHAT TO MEASURE: PHYSICAL AND CHEMICAL PARAMETERS

This session looked at various methods of measuring different water quality characteristics, and the constraints which must be considered when applying them. For example, measuring temperature, which affects the rate of all biological and chemical processes, must be performed in situ and is meaningless if performed later. The session described different types of parameters such as physical parameters which include temperature, pH, colour and transparency, and also chemical parameters including compounds such as nutrients, heavy metals and organic chemicals. It was illustrated that some parameters can influence the measured values of others, and that each parameter has its own requirements to be able to measure it accurately. The session concluded with an explanation that the selection of the most appropriate parameters depends entirely on the objectives of the monitoring programme.

3.2 ALTERNATIVE APPROACHES TO MONITORING

There are alternative approaches to collecting water quality data that can be considered in addition to traditional physical and chemical monitoring. Some of the main advantages of these are that they may be less expensive or may provide a greater spatial or temporal coverage. This session looked at different approaches including: biological, continuous monitoring and sensors, remote sensing methods and also citizen and community monitoring approaches, and identified advantages and disadvantages that should be carefully considered. The reasons for considering alternative approaches were also reviewed, such as: financial constraints, restricted access to advanced instrumentation; the need for large spatial coverage and the need for high frequency of data collection.

Figure 6: Participants engaging during a discussion session and deliberating on their group's task

3.3 INCORPORATING HYDROLOGICAL MEASUREMENTS INTO WATER QUALITY MONITORING PROGRAMMES

The importance of collecting hydrological data was described in detail during this session, and how complementary hydrological data can aid correct interpretation of water quality data. For example, nutrient concentrations in a river may rise during high flow conditions following a rain storm event. Recording river flow, allows the relationship between flow and concentration to be determined, rather than assuming the concentration fluctuates for no apparent reason. Furthermore, by monitoring both flow and concentration it is possible to estimate the total export of a substance from a catchment – for example, how much phosphorus is exported from a river catchment to the sea.

The basic hydrological measurements that should accompany all water quality monitoring programmes were also described. These include measurements, such as water discharge in rivers, residence time and thermal regime for lakes and reservoirs, and flow and water level for groundwaters. The session finished by describing various methods of measuring hydrological characteristics of freshwaters at different levels of complexity.

3.4 LOGISTICS AND PLANNING

This presentation emphasised the importance of careful planning to ensure that time and resources are used efficiently, and that the objectives are achieved within the lifetime of the monitoring programme. Fieldwork comprises a significant portion of the total cost of many programmes, and thorough planning during the design phase is necessary to ensure the samples can be collected in a safe and efficient manner. It was highlighted that for some measurements of water quality, the time between collection in the field, and analysis in the laboratory is critical. For an accurate result, this time-dependency must be incorporated at the planning phase of a monitoring programme. Examples of field checklists were given and the importance of health and safety of field personnel was emphasised. The recording of accurate data on field record sheets was described, and that some analyses require the sample to be collected in a certain type of bottle, or may need a specified preservative added at the time of collection.

3.5 QUALITY ASSURANCE AND CONTROL

Errors can be introduced at all stages of sampling and analysis, and data are not credible if their quality cannot be assured. This session covered the importance of quality assurance plans and the associated procedures, and how these can help to minimise errors. The importance of applying quality assurance to field, laboratory and data storage operations and how this should be considered at the monitoring programme design phase, was highlighted. An overview of internal and external quality control procedures in a laboratory and some practical measures for ensuring the quality of monitoring results in the field and in the laboratory were also considered. One of the key messages during the session was the need to assign adequate resources to implement a quality assurance plan - approximately 10 to 20 per cent of the total resources needed for a monitoring programme should be devoted to quality assurance, i.e. financial, technical and personnel.

3.6 GROUP EXERCISE - PARAMETER SELECTION

During the second group exercise, participants were asked to suggest parameters that would best meet one of three monitoring programmes objectives. The scenario objectives were:

A. To assess ambient water quality in a river.
B. To monitor raw surface water that will be used for drinking without treatment.
C. To monitor the impact of untreated sewage discharge.

Participants successfully identified the parameters that would need to be included to fulfil each of the monitoring programme objectives.

4 DAY 3

Day 3 followed a similar structure to previous days, finishing with a final group discussion and closing session. A summary of each session is provided below along with the detailed programme provided in Annex 2.

4.1 DATA MANAGEMENT PLANNING

Accurate and quality-assured water quality monitoring data are the prerequisite for subsequent data analysis, interpretation and sound management of surface water resources. This session looked at the data component of design and implementation of a monitoring and assessment programme and how effective data management helps to:

- meet the data quality objectives and information requirements;
- maximize the effective use and value of data and information products;
- ensure appropriate use of data and information;
- facilitate data sharing and re-use; and
- ensure sustainability and accessibility in the long term for re-use of data.

Well planned and managed data storage is essential to ensure data integrity, to maximize use of data and to meet information requirements of a monitoring programme. The need to plan and ensure quality control and assurance measures through the entire data life cycle was highlighted, and examples of good practice were provided.

4.2 WATER QUALITY MONITORING FOR THE SUSTAINABLE DEVELOPMENT GOAL INDICATOR 6.3.2

This session described the background of Agenda 2030 and the Sustainable Development Goals, with a focus on indicator 6.3.2 on ambient water quality. The role of implementing the indicator methodology in measuring progress towards target 6.3 was described, particularly its role in assessing the effectiveness of measures to reduce pollution of freshwaters and measure change over time in the quality of water in rivers, lakes and groundwaters. An overview of the methodology was given, and the results from the 2017 global data drive were summarised. Figure 7 shows the indicator score reported (colour of circle); an estimation of the proportion of the country included in the calculation (size of circle) and the monitoring effort (location of circle) - countries located at the upper right of the figure used considerably more data than those located at the bottom left.

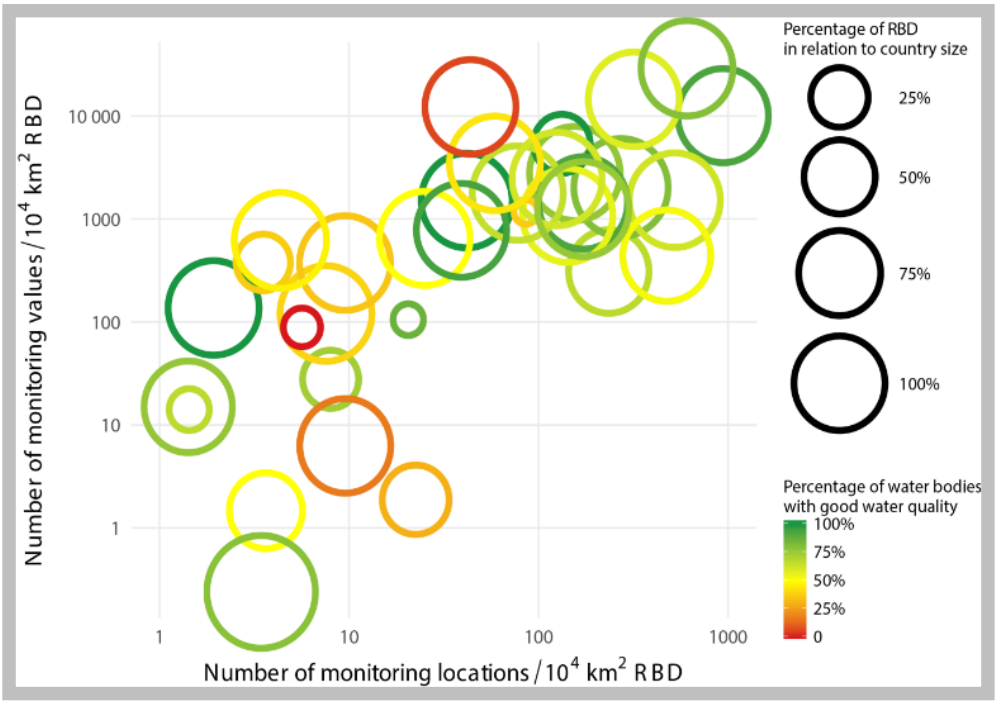

Figure 7 Summary of the 2017 indicator 6.3.2 results (UN Environment, 2018)[2]

4.3 DATA QUALITY ASSURANCE

This session examined the importance of quality assurance processes for water quality data. It looked at the various steps of data collection, data entry and transcription and the potential for the introduction of errors. The four basic activities of data quality assurance were described, namely ensuring the quality of data before entry into the data storage; strategies for preventing errors from entering the data storage; monitoring and maintaining data quality during and after data entry; and documenting the credibility and quality of stored data. If these steps are followed it is then possible to detect and clean-up data errors that were introduced during the various steps of data transcription and to interpret anomalous values.

4.4 GROUP EXERCISE - MONITORING PROGRAMME DESIGN SIMULATION

Participants were divided into the same groups as previously, and were each given the same task. Each group was asked to propose a water quality monitoring programme based on background information provided. The objective of the programme was to support the protection of the aquatic ecosystem in a fictitious river basin. The groups were supplied with maps of the river network and catchment information including elevation (Figure 8) and land use. Additional relevant information was also provided such as water use in the catchment and possible sources of pollution. Participants were also given a limited historical water quality dataset for the catchment and rainfall data for two locations.

[2] UN Environment (2018) *Progress on Ambient Water Quality, Piloting the monitoring methodology and initial findings for SDG indicator 6.3.2*. Available at: http://www.unwater.org/publications/progress-on-ambient-water-quality-632.

Participants were asked in their groups to apply the monitoring programme design process chart and prepare a presentation proposing a monitoring programme to a group of stakeholders and a local water management authority. The suggested layout of the proposal included:

- The objectives of the monitoring programme.
- Recommended monitoring approach and parameters.
- Proposed sample sites and frequency of sampling.
- Additional data and information needs.
- Quality assurance for the monitoring programme.
- Logistics and safety considerations.
- Recommendations for data storage and assessment.

Each group presented their proposal to the plenary, and an engaging feedback session involving numerous questions and clarifications from both participants and the GEMS/Water team followed.

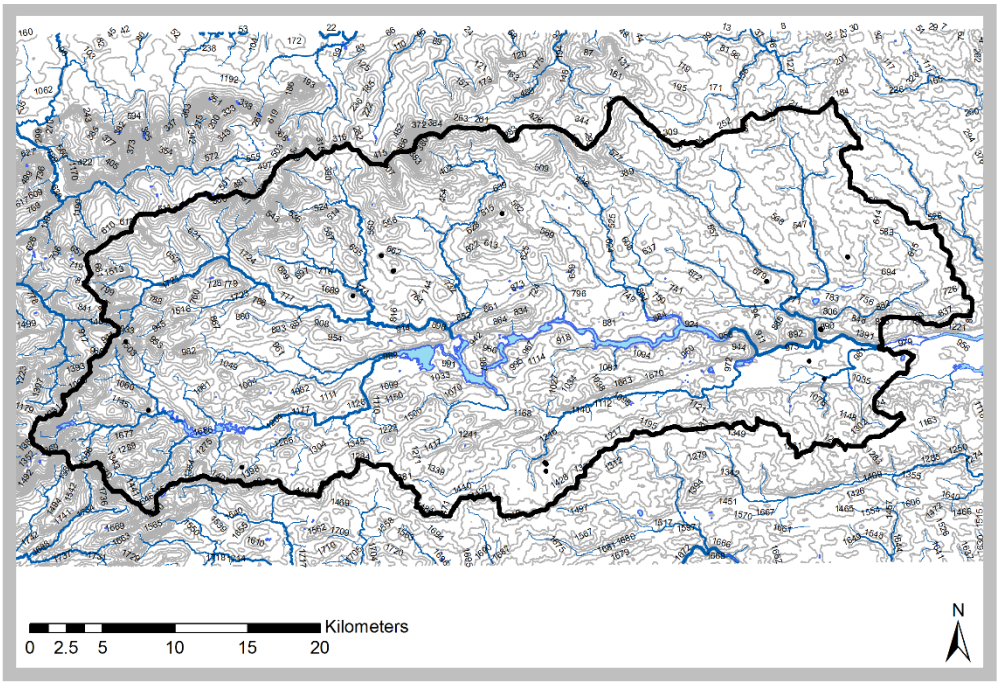

Figure 8: Example of information provided to participants for final exercise

5 WORKSHOP OUTCOMES

This training workshop addressed some of the capacity needs identified during the scoping phase of the GEMS/Water project plan. Fourteen participants from 13 countries were trained in monitoring programme and network design for surface water bodies. Additionally, participants were provided with training materials in electronic form to run further training initiatives in their own organisations.

Understanding the principles of good monitoring programme design is essential because it provides the foundation for many aspects of water quality management that future GEMS/Water training initiatives plan to build on. These planned initiatives include workshops and delivery of training

material focussing on QA/QC (quality assurance and quality control) procedures and also data management.

The feedback from participants was positive and encouraging (summarised in Annex 3). It confirmed that the training is meeting capacity development needs. The need for further training was highlighted, and a similar workshop on groundwater monitoring were considered to be useful. The benefit of using examples of water bodies from the region was highlighted.

In addition to addressing some of the capacity gap, the workshop served to strengthen links with the West Africa Francophone region, and especially to reinforce connections with the host country. Senegal was involved in UN Water's Proof of Concept phase for the SDG 6 indicators in 2015 and 2016 and has had a long-standing association with GEMS/Water. Professor Salif Diop of the Cheikh Anta Diop University has been involved for many years and joined the workshop on day three to welcome and discuss with participants. The enthusiasm of the Ministry of Hydraulics and Sanitation, and especially of DGPRE, to continue to champion freshwater quality management best practice in the region is highly valued. Additionally, Senegal is to host the next World Water Forum in Dakar in 2021, and as a direct result of the workshop, GEMS/Water are working with DGPRE to drive a project forward that will test the scope for engaging citizens in a water quality monitoring initiative, that will be showcased at the Forum in 2021.

Figure 9: Group photo of participants and the GEMS/Water team

6 ANNEXES

Annex 1 – Participant List

NOM ET PRENOM	Fonction/Structure/PAYS
AVOCANH Gautier	Chef du Service Laboratoire Central d'Analyse des Eaux/Direction Générale de l'Eau/BENIN
Samaké OUMOU LY	Chef du service technique du laboratoire National des Eaux/MALI
AGOUDA Kpadja	TOGO
Hamidine Amina Amatou	NIGER
OUATTARA Cheick Abdramane	BURKINA FASO
NELNGAR YOUNANE	TCHAD
RYUMEKO Melchior	BURUNDI
Adama GAYE	Environnement et qualité Eau OLAC/SENEGAL
KOLIA Marius	Direction Générale des Ressources en Eau/Côte d'Ivoire
Marie Rose MUKONKOLE MAYELE	Ministère de l'Environnement/Direction des Ressources en Eau/RDC
Bocar Adallah SALL	Direction de la Gestion et de la Planification des Ressources en Eau/Sénegal
DINGA Jean Bienvenu	Responsable du Service Hydrologique National. Enseigneur Chercheur à l'Université Marien Ngouabi.
Pierre LAMAH	Expert point focal de la Commission des Nations Unies pour la Développement Durable/Ministère de l'Environnement, des Eaux et forêts/GUINEE
NZOUBA Aurelien	Chef de service contrôle qualité de l'eau/Direction Générale de L'Eau/Ministère de l'Eau et Energie
Deborah Chapman (d.chapman@ucc.ie)	GEMS/Water Capacity Development Centre
Greg Beechinor	GEMS/Water Capacity Development Centre
Stuart Warner (s.warner@ucc.ie)	GEMS/Water Capacity Development Centre

Annex 2 – Workshop Programme

GEMS/Water Capacity Development Centre training workshop:

Monitoring programme and network design for surface water bodies

2 - 4 July 2018

Le Ndiambour Hotel, Dakar, Senegal

Monday 2 July		**Facilitator**
08.30 – 09.00 09.00 – 09.15 09.15 – 09.30 09.30 - 10.30	Registration Official welcome Brief overview of GEMS/Water and objectives of the workshop Introduction of participants and their national water quality monitoring activities	 Niokhor Ndour Deborah Chapman All participants
10.30 – 11.00	Refreshments	
11.00 – 12.00	Monitoring for information and management	Deborah Chapman
12.00 – 13.00	Understanding your waterbody for monitoring programme design: ecology and hydrology	Stuart Warner
13.00 – 14.00	Lunch	
14.00 – 15.00	Monitoring and assessment process overview	Greg Beechinor
15.00 - 15.30	Monitoring site and station selection	Stuart Warner
15.30 – 16.00	Refreshments	
16.00 – 17.00	Site selection group exercise	G. Beechinor, D. Chapman, S. Warner
17.00 – 17.30	Discussion and group feedback	G. Beechinor, D. Chapman, S. Warner
18.00 – 20.00	Welcome reception	

Tuesday 3 July		**Facilitator**
08.30 – 09.30	Choosing what to measure: physical and chemical parameters	Greg Beechinor
09.30 – 10.30	Alternative approaches for monitoring water quality	Deborah Chapman

10.30 – 11.00	Refreshments	
11.00 – 11.45	Water quality variability and sampling frequency	Greg Beechinor
11.45 – 12.30	Incorporating hydrological measurements into water quality monitoring programmes	Stuart Warner
12.30 – 13.00	Discussion	
13.00 – 14.00	Lunch	
14.00 – 14.30	Logistics and planning	Stuart Warner
14.30 - 15.30	Quality assurance and control	Deborah Chapman
15.30 – 16.00	Refreshments	
16.00 – 17.00	Parameter selection group exercise	G. Beechinor, D. Chapman, S. Warner
17.00 – 17.30	Discussion and group feedback	G. Beechinor, D. Chapman, S. Warner

Wednesday 4 July		**Facilitator**
08.30 – 09.30	Data management planning	Dmytro Lisniak
09.30 – 10.00	Water quality monitoring for the Sustainable Development Goal indicator 6.3.2	Stuart Warner
10.00 – 11.00	Data quality assurance	Dmytro Lisniak
11.00 – 11.30	Refreshments	
11.30 – 11.45	Introduction of group simulation exercise	Deborah Chapman
11.45 – 13.00	Group work on monitoring programme design simulation	G. Beechinor, D. Chapman, S. Warner
13.00 – 14.00	Lunch	
14.00 – 15.00	Continue group work on monitoring programme design simulation	G. Beechinor, D. Chapman, S. Warner
15.00 – 15.30	Group presentations	All participants
15.30 – 16.00	Refreshments	
16.00 – 17.00	Discussion and feedback session	G. Beechinor, D. Chapman, S. Warner
17.00 – 17.30	Close of workshop	

Annex 3 – Workshop Feedback Summary

		Rating									
Question No.	**Question**	**Disagree Strongly**	**%**	**Disagree mildly**	**%**	**Don't know/No comment**	**%**	**Agree mildly**	**%**	**Agree strongly**	**%**
1	The objectives of the workshop were clear	0	0%	0	0%	0	0%	2	15%	11	85%
2	The content of the workshop was relevant to you	0	0%	0	0%	0	0%	4	31%	9	69%
3	The workshop introduced you to new topics and ideas	0	0%	0	0%	0	0%	4	31%	9	69%
4	Presentations were generally clear and well presented	0	0%	0	0%	0	0%	6	46%	7	54%
5	You will use what you have learned in the workshop in your current role	0	0%	0	0%	1	8%	2	15%	10	77%
6	The workshop was enjoyable	0	0%	0	0%	0	0%	3	23%	10	77%

A: Did you find any section or topic of the workshop particularly useful?

The section on the indictor for SDG 6.3.2	The determination of physical and chemical parameters to be used at each station.	Storage of data.	Defining objectives/Conception of the programme	Methods of monitoring water quality
1*	3	1	2	2

*numbers denote the number of participants agreeing with statement

B: Did you find any section of the workshop of little interest or use to you in your current role?

The data management section, as no programme specialist present.	All sections relevant
1	12

C: Are there any topics that were not included that you think should be? It so, suggest topics

Data management (processing/statistical data analysis/methods/parameters/ dissemination)	Overview of water quality more broadly (e.g specific to regional/country/global)	Water quality modelling	Economic aspect of water quality/monitoring/ass essment	Bio-monitori ng using diatoms	GIS applicati on
6	1	1	1	1	1

D: Are there any topics that were not included that you think should be? If so, suggest the topics.

Flow rates and the concentration of surface water	Groundwater Quality	Data Management/Interpretation (including training on the use of excel and access)	Capacity building and countries advanced in water quality monitoring to share experiences with other countries	Flow rates and the concentration of surface water	Groundwater Quality
1	2	3	1	1	2

E: Have you any other comments or suggestions about any aspect of the workshop?

Very important workshop
Give examples of African basins
Continue to organise workshops to further the understanding of the subject
Present images of existing quality control stations
Communicate practical information, like accommodation, subsistence, and any other information necessary for a successful workshop
Groundwater quality monitoring in another similar workshop
More information on financial plan of UN Environment
Gems Water needs to advocate with technical and financial partners to support countries in measuring materials for key water quality metrics
Can GEMS provide a support for monitoring networks of two main rivers for each participating country and member?