United Nations Environment Programme

Operational Guide

for Data Submission Version 4

GEMS Water

Global Environment Monitoring System
Water Programme

Operational Guide for Data Submission

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UN GEMS/Water Programme Office
c/o National Water Research Institute
867 Lakeshore Road
Burlington, Ontario, L7R 4A6 CANADA
website: http://www.gemswater.org
tel: +1-306-975-6047
fax: +1-306-975-5663
email: info@gemswater.org

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1. Introduction

Established in 1978, the UNEP GEMS/Water Programme is a primary source for global water quality data. It is a multifaceted water science centre oriented towards building knowledge on inland quality issues worldwide. Key activities include monitoring, assessment and capacity building. The twin goals of the programme are to improve water quality monitoring and assessment capacity in participating countries, and to determine the state and trends of regional and global water quality.

These goals are implemented through the GEMS/Water data bank, called GEMStat, with water quality data from more than 100 countries, and over two million entries for lakes, reservoirs, rivers and groundwater systems. GEMS/Water activities add value to country level data by creating global and regional water quality assessments. The programme also carries out assessments on a range of water quality issues and methodologies. GEMS/Water data have been used by many organizations, including the UN system and universities around the world.

The role of GEMS/Water is highlighted in *Agenda 21*, Chapters 18 — *Freshwater*, and 40 — *Information for Decision Making*. While the programme belongs to the whole UN system, it functionally fits into the Division of Early Warning and Assessment (DEWA) of UNEP. It is overseen by an UN-appointed Steering Committee and has a Technical Advisory Group that provides scientific advice. The Programme is hosted by the Government of Canada in Ontario.

The hydrological counterpart of GEMS/Water is the Global Runoff Data Centre (GRDC) of the World Meteorological Organisation, which is based in Koblenz, Germany. http://grdc.bafg.de.

GEMS/Water operations include four core results areas, and one cross cutting function:

1. Global water quality data warehousing (GEMStat);
2. Global water quality assessments;
3. Data integrity (QA/QC); and
4. Building water quality capacity; and integrated though these four areas,
5. Meeting operational performance standards.

Some specific and ongoing examples of activities are:

a) Collaborating with UN member states in establishing new water quality monitoring systems and strengthening existing systems;
b) Improving the validity, interoperability and comparability of water quality data between member states; and
c) Assessing the state and trends of the pollution of water by some persistent and hazardous substances on a long-term basis.

More information, such as milestones, achievements, other activities, publications, media releases, etc., is available at http://www.gemswater.org. GEMStat, the global online water quality database is accessible at http://www.gemstat.org.

2. Purpose of this Operational Guide

This document outlines the process for how UN member states, through their identified Focal Points, can contribute to the global water quality database, GEMStat, by submitting national environmental water quality data. This activity forms the basis by which Focal Points can participate in, and benefit from, GEMS/Water activities. Information and guidance are provided on the following topics:

- Objectives and benefits of global and regional water quality monitoring networks;
- A description of the UN global water quality monitoring network, and how to become involved in the network;
- A description and rationale for the selection of stations from where relevant water quality data are to be collected;
- Reference to, and rationale for, methods that are useful in the monitoring of water quality and quantity;
- A complete list of water quality variables (parameters or determinands) that GEMStat warehouses, and the database codes associated with each of these;
- References and methods for the management and quality control of data; and
- The procedure for the submission of data to GEMStat, including spreadsheet and text forms, and GEMSoft, a data submission software application.

Some of the main benefits that participation can bring to Focal Points include:

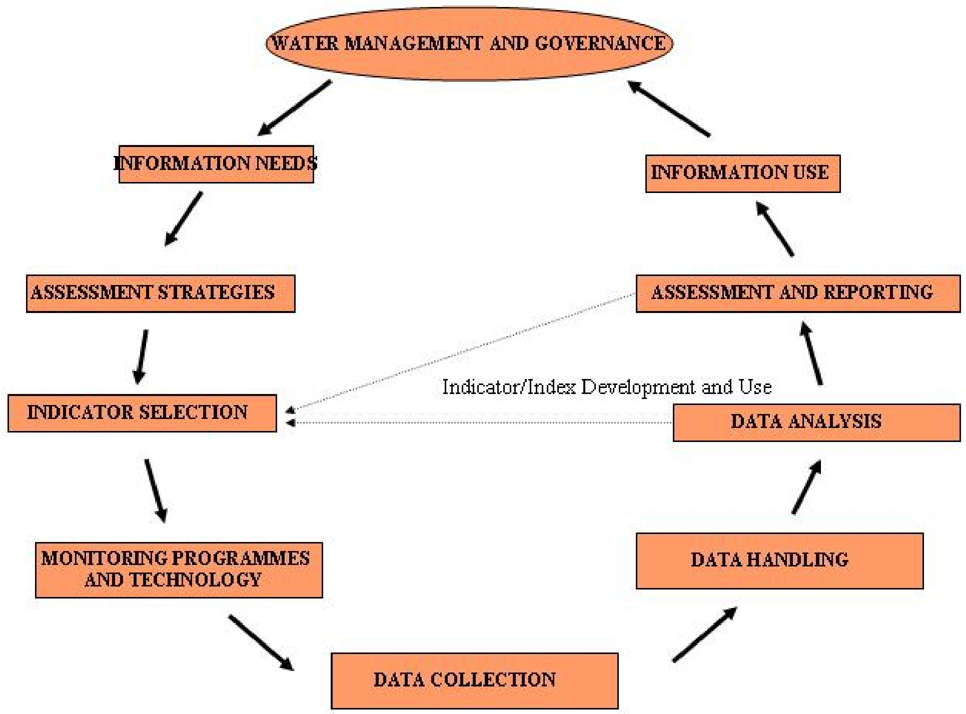
Participation in achieving the United Nations' work on water, including the Millennium Development targets on biodiversity, water and sanitation.

- Information on the quality of water entering upstream in transboundary waters or shared coastal areas.
- Information on water quality in regions from which member countries import fruit and vegetables that may be a potential source of human pathogens or contaminants.
- Access to data on similar aquatic systems in other countries that can be used for comparison purposes by water authorities.
- Access to publications and methods that allows readers to compare data from different laboratories from around the world.
- Water quality laboratories can participate in our international Laboratory Performance Evaluation Studies.
- Training in water quality monitoring and assessment.
- Laboratory assessments to improve laboratory capacities (i.e., policy and objectives, quality control, qualification of personnel, documented analytical methods, sample/data/workload management, remedial actions, traceability, etc).
- Safe, off-site storage and retrieval of valuable national water quality data, in case of an unfortunate event resulting in the local copy being accidentally lost.
- Links to an international network of water quality data experts.

3. Information Needs and Objectives

The process of monitoring and assessment is a cyclic sequence of related activities that starts with the definition of information needs, and ends with the use of the information product for further planning and decision-making (see Figure 1). The successive activities in this monitoring cycle should be specified and designed based on the required information product as well as the preceding part of the cycle. The evaluation of obtained information may lead to new or redefined information needs, thus starting a new sequence of activities. Monitoring should be seen as a dynamic and reiterative management process that should be improving over time.

Figure 1: Elements of the Monitoring Cycle



3.1 United Nations Water Assessment Priorities

GEMS/Water supports three UN water assessment priorities:

1. Determination of natural inland water qualities in the absence of significant direct human impact; and
2. Determination of long-term trends in the levels of critical water quality indicators in inland water resources; and
3. Determination of the fluxes of toxic chemicals, nutrients, suspended solids and other pollutants from major river basins to the continent/ocean interfaces.

In addition, several issues at the global and/or regional or sub-regional levels are significant. These include:

- Organic wastes from municipal sewage discharges and agro-industrial effluents;
- Eutrophication of surface waters as a result of point and non-point input of nutrients and organics;
- Irrigation areas which are threatened by salinization and polluted irrigation return waters;
- Agro-chemical use, fertilizers and pesticides leading to surface and groundwater contamination;
- Industrial effluents containing a variety of toxic organics and inorganics;
- Mining effluents and leachates from mine tailings affecting surface and groundwaters on a large scale; and
- Acidification of lakes, rivers and groundwaters, resulting from the long-range atmospheric transport of pollutants.

National monitoring programs are essential for water resources planning and economic and environmental decision making. The monitoring and assessment function of GEMS/Water is driven by the requirement for a consistent international database that can produce a variety of global and regional assessments by water- related agencies. GEMS/Water data have contributed to numerous water assessment reports, which are listed on the website.

4. UNEP GEMS/Water Global Network

4.1 Monitoring Strategy

Meeting the monitoring data requirements for global water quality assessment means that a selective network of strategically located monitoring stations should be present around the world. As a UN body, GEMS/Water recognizes that it cannot achieve its mandate without the collaboration and involvement of member states. The strategy for developing a better understanding of global water quality is based on the participation of as many stakeholders as possible in the collection, storage, use and assessment of water quality and quantity information. GEMS/Water strives to create an active and extensive global network, which includes all member states of the UN system, as well as other institutions involved in water quality monitoring and reporting.

Through officially designated Focal Points, UN member states voluntarily submit water quality and quantity information to the global database. It is important that each country has an operating water quality monitoring network to meet its own national water resource needs, and that GEMS/Water obtains relevant data/information from an already set up network of country monitoring systems.

The networking approach ideally is based on:

- All countries with existing national monitoring systems have the capability to provide continuous records of relevant information and data on water quality and metadata to the GEMS/Water database, GEMStat;
- Monitoring and reporting systems in each country can support the requirements of the GEMS/Water global monitoring system;
- Interaction with GEMS/Water and the provision of data and information is done on a voluntary, yet systematic, basis;
- Stakeholders are able to gain easy access to the data and information that are stored in GEMStat;
- Regular reports on the status of global and regional water resources are made available to stakeholders;
- Network members are able to interact and benefit from the information and services offered by GEMS/Water;
- Network members interact amongst themselves in the sharing of information and ideas on water quality monitoring and reporting; and
- Stakeholders are able to respond in a synergistic way to situations where water resource management would benefit from joint ventures and partnerships.

4.2 National Focal Points and Collaborating Focal Points

The United Nations currently has 191 member states and, for purposes of information and database management, GEMS/Water allocates a country code to each of these countries. The current status of this network and the formal participation of members are described in the GEMS/Water *State of the Global Network and Annual Report*.

Each federal government responsible for national water quality monitoring and assessment should formally identify a National Focal Point (NFPs) by identifying an agency and a representative official charged with engaging with GEMS/Water activities.

The primary role of focal points is to submit national water quality data and information on a variety of parameters, on a yearly basis. Thus, the NFP should be a federal environmental water quality monitoring and assessment authority. Collaborating Focal Points (CFPs) are agencies with similar functions yet are not federal structures, but rather are universities or non-governmental organizations. The institutional structures of focal points are principally:

1. The official designation of the NFP can be done through a letter of agreement between GEMS/Water and a specific ministry or federal government department. A memorandum of understanding can be put in place if required;
2. The NFP should be easily accessible to policy and decision-makers, scientists, planners, researchers and the general public;
3. The NFP should be located in a national organization where there is the best concentration of water resource information and expertise;
4. The NFP should be staffed by water quality professionals and have information services, computing and telecommunications support;
5. Participating governments are expected to ensure that sufficient resources are available to their NFPs to participate in the GEMS/Water programme. The major cost components are office space and laboratory facilities, and communications costs;
6. The NFP should appoint a Focal Point Representative who has the status of national Head of Environmental Water Quality Monitoring or equivalent; and
7. Collaborating Focal Points (CFPs) are participating non-governmental organizations, such as universities, scientific institutions and not-for-profit organizations and programmes. CFPs are designated on a case by- case basis, with their roles and outputs determined by mutual agreement. CFPs can be regional or sub-regional in scope and activity.

Focal Points should provide a variety of input to GEMS/Water and this will vary according to each country and its monitoring programme for water resources. Some of the main services and functions, within capacity are:

- Provision of a national water quality information centre accessible to the public;
- Submission of agreed national water quality datasets to GEMS/Water, on a range of parameters at regular intervals;
- A source of national environmental water quality data and information;
- Development, management and maintenance of the national monitoring and water quality database;
- Stewardship of a national QA/QC programme;
- Development, management and maintenance of a national environmental water quality website;
- A distributor of GEMS/Water promotional and communications materials;
- A distributor of water quality awareness fact sheets and/or leaflets on topics of national interest available in local language(s);
- A contributor to regional water quality databases (if applicable);
- Submission of six monthly query-response statistics reports and raw datasets on key parameters covering chemicals, biota, organics, metals and ions;
- Promotion of GEMS/Water at national level;
- A contributor of information to GEMS/Water for UNEP Governing Council meetings;
- Development of links and liaison with national/international NGOs on environmental water quality monitoring;
- Participation in sub-regional GEMS/Water network activities (if applicable);
- Assistance in regional network management meetings and training courses in cooperation with GEMS/Water;
- Ensuring that water quality monitoring is coordinated with hydrological monitoring under the auspices of the Global Runoff Data Centre of the World Meteorological

Organization.

To reciprocate with focal points, GEMS/Water in turn provides services and products to each individually, and collectively as a network. Full descriptions of the roles and expectations of both GEMS/Water and focal points are outlined in the *National Focal Points Specifications*.

5. Monitoring Networks and Data Collection

5.1 Setting Up National Water Quality Monitoring Networks

The design and setting up of a national water quality monitoring system demand considerable time, effort, and resource investment, as most water authorities are well aware. For a country without an existing monitoring system, it may take many years to establish one with the capacity to successfully provide good quality information that can be used for decision-making and planning. (see Box 1).

It is recognized that the monitoring capacity and capabilities of countries will differ. Some countries will already have sophisticated monitoring systems in place whereas others may not. It is important that GEMS/Water knows about the capacity of all countries within the network. For countries that require assistance in the setting up, or operating, their national water quality monitoring system, GEMS/Water is willing, on request, to give advice and assistance.

Box 1

Principles for an Effective Water Quality Monitoring and Assessment Programme

1. Information needs must be defined first and the monitoring programme designed to meet them.
2. Adequate financial support must then be obtained.
3. The type (river, lake, reservoir, wetland, ground water) and trophic state (oligotrophic to hypertrophic) of the water body must be fully documented through preliminary surveys, particularly the spatial and temporal variability within the whole water body.
4. The appropriate components (water, particulate matter, biota) must be chosen.
5. The parameters, type of samples, sampling frequency and station location must be chosen carefully with respect to the information needs.
6. The field equipment and laboratory facilities must be selected in relation to the information needs.
7. A complete and operational data treatment scheme must be established.
8. Monitoring the quality of the aquatic environment must be coupled with the appropriate hydrological monitoring.
9. The quality of data must be regularly checked through internal and external controls.
10. The data should be given to decision makers not as a list of parameters and their values, but interpreted and assessed by experts with relevant recommendations for management action.
11. The programme must be evaluated periodically, especially if the general situation or any particular influence on the environment is changed, either naturally or by measures taken in the catchment area.
12. Effective collaboration mechanisms are also required between monitoring jurisdictions (local, regional, basin, and national levels.)

Source: Based on the 10 Principles of the European Environment Agency

5.2 Procedure for Registering Country Networks

All NFPs and CFPs should expect a collaborative and interactive process with GEMS/Water, during which the details of the network of selected stations in the respective country (e.g., their category type, the rationale behind their selection, specific characteristics, data that can be monitored etc.) are discussed and agreed on prior to the submission of data to GEMS/Water. GEMS/Water is willing to provide advice, on request, on the setting up of new networks, as well as to evaluate existing stations within NFP and CFP networks.

5.3 Water Quality Parameters

The UNEP Technical Advisory Group for GEMS/Water has recommended a set of core water quality variables that the GEMS/Water monitoring programme should endeavor to collect information (see Table 1). These have been selected to cover the potential impacts of key issues that are considered to be of significance at the global and/or continental or sub-continental level. A list of water quality parameters along with method codes is given in the *Analytical Methods for Environmental Water Quality* that is available at http://www.gemswater.org (GEMS/Water and International Atomic Energy Agency, 2004).

These parameters can be separated into seven water quality categories, notably:

1. General water quality including some physical parameters
2. Dissolved salts / Ionic balance
3. Nutrients
4. Organic matter
5. Microbial pollution
6. Inorganic contaminants (dissolved and particulate)
7. Organic contaminants.

NFPs and CFPs are encouraged to include as many of the variables within their national (or regional/basin) monitoring programmes.

There are many comprehensive water quality monitoring guidelines currently available. Focal Points should decide on the methods that are most suitable for their own situation. GEMS/Water does not wish to be prescriptive in which methods are used as it is recognized that it is unlikely that all countries could adopt and use identical methods. GEMS/Water provides access to technical guides that can be consulted for the setting up of monitoring networks, and the selection of appropriate field and laboratory methods. In cases where NFPs are not able to decide on which method to use GEMS/Water is prepared to advise.

Table 1. Parameters List

Water Quality Category	GEMStat Parameters	
Hydrological and Sampling Variables	Instantaneous discharge	
Physical/Chemical Variables	Water discharge/level (GRF) Total suspended solids (R) Temperature pH (GRF)	Electrical conductivity Dissolved oxygen Transparency (L)
Major Ions Dissolved salts / Ionic balance	Calcium Magnesium Sodium Potassium Chloride Fluoride (G.W.)	Sulphate Alkalinity Sum of cations Sum of anions Sodium adsorption ratio
Nutrients	Nitrate plus nitrite Ammonia Organic nitrogen, dissolved Organic nitrogen, particulate	Total phosphorus, dissolved (R, L) Total phosphorus, particulate Total phosphorus, unfiltered (R, L)

		Silica reactive (R, L)
Organic matter	Organic carbon, dissolved Organic carbon, particulate BOD	COD Chlorophyll *a* (R, L)
Microbiology	Faecal coliform Total coliforms	Giardia Cryptospiridium
Metals Inorganic contaminants (measured as dissolved, particulate, and/or total; particulate concentrations are essential for GRF stations)	Aluminium Arsenic Boron Cadmium Chromium Copper Iron	Lead Manganese Mercury Nickel Selenium Zinc
Organic contaminants	Aldicarb Aldrin Altrazine Benzene 2, 4-D DDTs Dieldrin Lindane	Total hydrocarbons Total chlorinated hydrocarbons Total polyaromatic hydrocarbons PCBs PBDEs (polybrominated diphenyl ethers) Phenols Toxaphene

Basic variables to be monitored at all GEMS/Water stations. (R) Basic variables for river stations only. (L) Basic variables for lake/reservoir station only. (G.W.) Basic variables for ground water stations only. (R, L) Basic variables for river, lake/reservoir stations only. (GRF) Essential for Global River Flux monitoring stations.

5.4 Station Selection

There are three types of monitoring stations in the GEMS/Water global monitoring network "*baseline*," "*trend*" and "*flux*" stations.

Baseline Stations are typically located in headwater lakes, undisturbed upstream river stretches, and in aquifers where no known direct diffuse or point-sources of pollutants are likely to be found. They are used to establish the natural water quality conditions; to provide a basis for comparison with stations having significant direct human impact (i.e., trend and global river flux stations); to determine, through trend analysis, the influence of long-range transport of contaminants and of climatic changes.

Trend Stations are typically located in major river basins, lakes or aquifers. They are used to follow long-term changes in water quality related to a variety of pollution sources and land uses; to provide a basis for the identification of causes or influences on measured conditions or identified trends. Since trend stations are intended to represent human impacts on water quality, the number of trend stations is relatively higher than the other categories of stations, in order to cover the variety of water quality issues facing various basins. Ideally, each country should cover all major human influences on water quality. Most of the stations are located in basins with a range of pollution-inducing activities. However, some stations are located in basins with single, dominant activities. Some trend stations may also serve as global river flux stations.

Flux Stations are located at the mouth of rivers as they exit to the costal environment. They are used to determine integrated annual fluxes of critical pollutants from river basins to oceans or regional seas, thereby contributing to geochemical cycles. For calculation of chemical fluxes, it is essential that water flow measurements be obtained at the location of the global river flux stations. It is for this reason that GEMS/Water encourages station co-location with GRDC-designated stations.

Each Focal Point should engage in a process that selects and operates monitoring stations, which best represent the three categories. The selection of these stations should not be seen by countries that already have monitoring networks as an expansion or addition to existing monitoring networks, but rather the designation of existing stations as GEMS global network stations because they meet the specifications of the three categories.

5.4.1 Site-Specific Criteria

The selection of GEMS/Water-designated stations should take into consideration various factors. Site-specific criteria are those that relate mainly to the physical location of the stations so that they best match up with the category specifications. These are presented in Table 2.

Table 2: Station Types and Site-Specific Criteria

Station Type	Basic Selection Criteria	Water Type
Baseline Station	• in small undisturbed basins	• Headwater lakes • Upstream river stretches • Groundwater from aquifers in undisturbed areas
	• no source of pollutants	
	• no direct human activities (including roads)	
	• Avoid basin with a high proportion of metal-bearing rocks	
	• at least 100 km from major air pollution source (i.e., cities, industries etc.)	
Trend Station	• in medium-sized basins	• Lakes/Reservoirs (water residence time: (1-3 years) • Rivers • Groundwater
	• moderate time frame response to pollution and changes in land-uses	
	• Range of pollution inducing activities/or/single dominant activities (e.g. Industrial, municipal, energy, agricultural, mining etc.)	
Global River Flux Station	• basin priorization scheme includes importance of drainage area, population, major human activities, and significance of the river to receiving coastal waters	• Rivers
	• most downstream station not influenced by tides	
	• station must be representative of the cross-sectional characteristics of the river	
	• availability of flow measurement data at the location of water quality monitoring station.	

5.4.2 Influences on the Water Resource

The designation of stations is influenced by the type of water pollution issue(s) to be monitored, its importance and magnitude. The influences on water quality at the country level can include:

- Organic wastes from municipal sewage discharges and agro-industrial effluents;
- Eutrophication of surface waters as a result of point and non-point input of nutrients and organics;
- Irrigated areas which are threatened by salinization and polluted irrigation return waters;
- Agro-chemical use, fertilizers and pesticides leading to surface and groundwater contamination;
- Industrial effluents containing a variety of toxic organics and inorganics;
- Mining effluents and leachates from mine tailings affecting surface and

groundwaters on a large scale; and

- Acidification of lakes, rivers and even groundwaters resulting from the long-range atmospheric transport of pollutants.

5.4.3 Water Use

The choice of stations will also be influenced by the various uses of the water and by their location, relative magnitude and importance (Table 3). The degree of risk of accidental pollution will also be an important factor. Water being used downstream of a large urban area, or an underground water source near to industrial tips, imposes greater risk, requiring more supervision, than water being used upstream of any significant polluting discharges or remote from any potential pollutants.

Table 3: Water Uses and Criteria for Site Selection

Use	Criteria
All Waters	
Drinking and domestic use	Population served
Agricultural irrigation	Annual value of crops and population employed
Livestock watering	Numbers of animals, annual commercial value, population employed
Industrial use	
- low grade - e.g., cooling	National and local importance of factory
- high grade - e.g., food and drink	Annual value of products, population employed.
Surface Waters	
Commercial fisheries	Quality and value of catch, importance as a food, population employed
Sporting fisheries	Number of people and frequency of use, membership of clubs, value of fishing rights
Recreation	
- bathing	Number of people, frequency of use, membership of clubs, distance from urban areas, access to alternative waters
- boating	
- amenity	
Navigation	Quality and value of goods transported, people employed. (risk of silting or aquatic vegetation)
Drainage	Potential damage, remedial costs, population affected. (risk of silting or obstruction causing floods)

5.5 Preliminary Surveys

It is important to ensure that designated GEMS/Water stations are representative of the situation that is to be assessed. Preliminary surveys are necessary not only to select stations, but also to check the sampling site accessibility, the available sampling means (bridge, boats etc), the time elapsed between sampling and laboratory analysis, and the costs of a sampling trip.

Preliminary surveys assist in the identification of locations in which water quality is most unsatisfactory or critical. Surveys should not be confined to the proposed stations but should be broadened to cover other practicable sampling points in the water body. It is also desirable to carry out the surveys over a representative period.

For rivers, the preliminary survey may include several stations on a given river section and should check the lateral mixing at each site. Such surveys may be affected during extreme environmental conditions such as the rainy season for tropical regions, or in winter for Nordic or mountain stations. In lakes, the selection of sampling sites will be based on morphometry, stratification patterns as well as external influences. For ground waters, surveys should be carried out to draw a preliminary picture of water quality based on several boreholes, wells and/or springs in order to choose the most representative stations.

It is important that GEMS/Water obtain the characteristics of each station. Focal Points are requested to complete the Station Form (in Microsoft Excel and Word formats) which contains important descriptive information requirements for network stations (rivers, lakes and reservoirs, and groundwater stations) related to the global database. The form should be submitted to GEMS/Water before the submission of any water quality datasets.

5.6 Sampling Frequency

Sampling approach and sampling frequency will depend on an array of considerations, some of which include:

- Variability with time of water quality
- External influences that affect variability
- Cyclic variations (annual, monthly and diurnal cycles)
- Nature of the station (e.g. river, groundwater or lake)
- Variability of individual variables
- Information obtained from preliminary surveys
- Associated hydrological events.

Annual sampling frequencies for the different categories of global network stations are outlined in Table 4.

Table 4: Recommended Annual Sampling Frequencies for GEMS/Water-Designated Stations

Station Type	Type of Water Resource		
	Rivers, Streams	**Lakes, Reservoirs**	**Groundwaters**
Baseline	Minimum: 4, including high and low water stages Optimum: 12, i.e., monthly sampling, and fortnightly for total suspended solids	Minimum: 1 at turnover (sampling at lake outlet) Optimum: 1 at turnover and 1 vertical profile at period of maximum thermal stratification	Minimum: 2, once each during wet and dry seasons Optimum: 4 times per year
Trend	Minimum: 8-12 for large (ca: 100,000 km^2) and small (ca: 10,000 km^2) drainage areas Other issues: additional samples should be collected to capture extreme events (e.g., under ice, high runoff events, drought conditions	Eutrophication Issue: 8-12, including twice monthly during summer Other Issues: Minimal: 1 at turnover Maximal: 2, one at turnover, and one at period of maximum thermal stratification	Minimum: 1 for large, stable aquifers Maximum: 4 for small alluvial aquifers Karstic Aquifers: same as rivers
Flux	Large basins (>200,000 km^2) (1) 6, for some particulate metals (2) 8-12, for all other variables		

	Small basins (< 200,000 km^2) (1) 8-12, for basic monitoring variables (3) and for expanded nutrients, organic contaminants and some expanded metal monitoring (4) 6, for some particulate analyses (2)

(1) For global river flux stations: continuous record of water discharge and weekly sampling for total suspended solids are recommended.
(2) For particulate arsenic, cadmium, chromium, copper, lead, mercury, selenium, zinc.
(3) For temperature, pH, electrical conductivity, dissolved oxygen, calcium, magnesium, sodium, potassium, chloride, sulphate, alkalinity, nitrate plus nitrite, total phosphorus filtered and unfiltered, silica, chlorophyll A, organic carbon - dissolved and particulate, organic nitrogen dissolved and particulate.
(4) For dissolved and particulate fractions of aluminium, iron and manganese; and for dissolved arsenic, cadmium, chromium, copper, lead, mercury, selenium and zinc.

Data and information on GEMS/Water-designated stations should be reviewed on an annual basis so that the optimal sampling frequency for each station can be verified and a decision made, as to whether sampling frequency should be reduced or increased. This review is considered to be important as it can contribute to better water resource decision-making, save considerable time and money, and also ensure a process of data quality control (QA/QC).

5.7 Sampling Methods

Each water quality parameter requires selecting a sampling method that may or may not differ from the sampling method used for other variables, or may differ from that of the same parameter in a different setting. Many sampling methods are linked to an analytical method that is carried out at a later stage in a laboratory (e.g., they require pre-analysis procedures such as filtration, preservation and storage of samples). Many variables can be analyzed in the field using electronic and/or automated equipment. All of this will depend on the capacity and level of sophistication of the water quality monitoring network that the particular NFP or CFP is able to develop and operate.

Focal Points should select the most appropriate sampling method for each parameter based on capacity of the monitoring system, the category of station, cost of equipment, cost of operating, skills of personnel etc.

5.8 Analytical Methods

For each water quality parameter in Table 1, there are several analytical methods, the selection of which will depend on the facilities and equipment that are available. The decision on which method should be used lies with the NFP/CFP, but details and information on the analytical method should accompany any data that are submitted.

5.9 Quality Assurance / Quality Control (QA / QC)

Monitoring programmes should seek to generate data of reliable and consistent quality. Scientific credibility depends on data quality, which means that quality assurance/quality control (QA/QC) should be an integral component of the monitoring programme, not just the laboratory analyses. Focal Points are urged to ensure that all aspects of their monitoring programmes have QA procedures that are able to assess the quality of their data, and rapidly identify and correct circumstances when data are not of acceptable quality.

QA procedures and practices should focus on:

- Training staff so that QA becomes a standard practice;
- Ensuring that adequate filing and sample record systems are in place;
- Ensuring that all field and laboratory equipment, instruments, sampling containers,

reagents etc. are in clean and working order;
- Ensuring that correct sampling procedures are followed;
- Ensuring that sample locations are adhered to;
- Carrying out QA checks where overall precision (sampling and analytical) can be assessed through field replicate measurements/analyses;
    - Overall accuracy can be assessed through field spike analyses, and expressed as percent recovery. Sampling accuracy can be evaluated by comparing overall accuracy to measurement/analytical accuracy;
    - Sampling completeness is calculated based on the ratio of samples collected to samples that were planned, and is expressed as percent completeness;
- Ensuring adherence to the selected analytical procedures;
- Accuracy in the laboratory can be expressed as percent of a reference value using standard reference materials (where available) and calibrating reference techniques;
    - Accuracy expressed as percent recovery of analytical data can be assessed based on the analysis of spiked samples and reference materials;
    - The accuracy of water quality analyses for the selected methods should be known;
- Completeness of measurement data is based on the ratio of measurements made to measurements that were planned, and expressed as percent completeness;
- Completeness of analytical data is based on the ratio of samples that were analyzed to the number of samples that were collected, and expressed as percent completeness; and
- Ensuring that there is continual testing and scrutiny of data, particularly in relation to previous parameter values for the specific site.

5.10 Hydrological Data and Methods

Knowledge and understanding of hydrology is an important component of integrated water resource management and all water quality monitoring systems should be closely linked to a parallel process of hydrological monitoring. The planning, design and operation of both hydrological and water quality monitoring systems are highly interdependent.

Focal Points should develop capacity and understanding of the hydrological characteristics of water resources associated with the water quality monitoring network stations. The WMO has a comprehensive library of technical documentation on how to set up and manage hydrological networks, as well as linking these to water quality monitoring (see: http://www.wmo.int/index-en.html). The WMO (1994) Guide to Hydrological Practices provides detailed guidance for the day-to-day activities of hydrological services. Operation hydrology, and its applications to water management, are covered in 59 chapters and include many of the scientific and technological advances that have taken place since the 1970s: radar measurement of rainfall; loggers using solid-state memories; and the application of geographic information systems. It discusses a wide range of hydrological models including distributed models and contains information on how to select one for a specific purpose. The guide also deals with urban water resources management, sustainable water development, irrigation and drainage and other topics relevant to water management.

As mentioned above, GEMS/Water is concerned with the monitoring of hydrological data for river flux station as hydrological data are used to estimate mass movement of dissolved and particulate material into the oceans. The WMO Global Runoff Data Centre, also as mentioned above, is the source for global hydrological data for the estimation of mass material movement into oceans. Focal Points should strive to ensure that the siting and operation of their global river flux stations are synchronized with the simultaneous hydrological monitoring that feeds into the GRDC global monitoring network.

6.0 Data Management

GEMS/Water maintains the only global environmental water quality database, and associated software, in the UN system. The online searchable database, GEMStat, http://www.gemstat.org, provides access to statistical summaries of the datasets.

The steps for the inflow of data include:

- The collection of field data from the respective stations in the national monitoring system- based on those water quality parameters that are measured in the field;
- The collection of laboratory data for the respective stations, based on those water quality parameters that are analyzed in the laboratory;
- The entering of data into coded forms by the personnel and laboratories responsible for the monitoring of stations. These are then sent to the NFP/CFP;
- Checking and coordination of the network data forms by the NFP/CFP, the addition of coded hydrometric information, and then forwarding of these on to GEMS/Water;
- Processing of associated hydrological information for the Global River Flux Stations by the NFP/CFP and forwarding on to the GRDC;
- Submission of the data to GEMS/Water; and
- Feedback from GEMS/Water to the NFP/CFP on confirmation of the data and comment on any observed discrepancies.

It is important that this overall process follows stringent validation and verification controls, and it is, therefore, required that the conventions for the coding of data are followed exactly as given by GEMS/Water.

6.2 Station and Analytical Data Forms

The NFP/CFP should ensure that two types of information are submitted: station forms and data forms. The Station Form contains details about the monitoring sites and need only be completed once for each sampling location, **but must be submitted to GEMS/Water before any data can be processed**. All data are subsequently linked to the associated station by means of an allocated station number. The Data Form contains the analytical results for a specific sample that has been collected from one of the registered stations. One data form should be completed for each original water sample. The data form can also be used to change or delete data where necessary. Both forms are available in Microsoft Excel and Word formats, and instructions on how to fill them out are included in the document *Operational Guide: Instructions for Station and Data Forms.*

6.2 Verification and Correction Process

Each analytical result submitted to GEMS/Water will be tested against pre-assigned limits for reasonableness. In addition, a series of logical checks will be performed. These tests are designed primarily to pick up gross data translation errors and do not relieve the local laboratory or the NFP and CFP of responsibility for validating data before submitting them.

The Quality Control Error Listings are produced whenever errors are detected by the quality control logic during input of data to the computer system. Major errors will be referred back to the NFPs and CFPs for correction. Corrected data forms should be resubmitted.

Minor errors such as data entry errors will be corrected where possible by GEMS/Water using the source data forms.

7. Related Documents and Tools

To help Focal Points maximize their participation with the GEMStat database, the following sources should be considered along with this Operational Guide. They include:

- Operational Guide: Instructions for Station and Analytical Data Forms
- Analytical Methods for Environmental Water Quality
- Station Form (Microsoft Word and Excel formats)
- Data Form (Microsoft Word and Excel formats)
- NFP Specifications
- Directory of National Focal Points.

8. Other Sources and References

Australian Guidelines for Water Quality Monitoring and Reporting (2000)
http://www.deh.gov.au/water/quality/nwqms/monitoring.html

Canada National Water Quality Monitoring Branch
http://www.nwri.ca/monitoring/intro-e.html

China Valuation survey on valuing water quality improvements in the Beijing Metropolitan Region carried out as part of the China Rural Water Project.
http://www.cserge.ucl.ac.uk/China_Water.pdf

CLEAN-India: An environment assessment, awareness and action programme
http://www.cleanindia.org/index.htm

European Environment Agency - Reports - Surface water quality monitoring.
http://reports.eea.eu.int/92-9167-001-4/en

Florida Department of Environmental Protection (FDEP) Ground Water Quality Monitoring Network
http://www.dep.state.fl.us/water/monitoring

India Central Pollution Control Board
http://www.cpcb.delhi.nic.in/ar2003/ar2-3ch8.htm

IALC Africa: The African Water Page.
http://ialcworld.org/links/water.html

ISO - International Organization for Standardization
http://www.iso.ch/meme/TC147.html
http://www.iso.ch/iso/en/stdsdevelopment/tc/tclist/TechnicalCommitteeDetailPage.TechnicalCommitteeDetail?COMMID=3666

Japan Water Quality Evaluation Method
http://nett21.gec.jp/CTT_DATA/WMON/CHAP_6/html/Wmon-187.html
http://nett21.gec.jp/CTT_DATA/WMON/CHAP_3/html/Wmon-041.html

Maharashtra State Surface Water Data Centre
http://www.hydrologydatainfo.org/default.htm

Manufacturers and suppliers of water analysis instrumentation (instruments for water quality

testing)
http://www.zhdanov.ru/classified-catalogue/water-analysis-instrumentation.htm

National Academies Press, Measures of Environmental Performance and Water Quality.
http://books.nap.edu/books/0309054419/html/227.html

New Zealand Water Quality Monitoring
http://www.deh.gov.au/water/quality/nwqms/

Rodrigues de Aquino, A,. Minimum Requirements for Reporting Analytical Data
http://www.iupac.org/publications/pac/2003/pdf/7508x1097.pdf

United Nations Economic Commission for Europe Water Convention Task Force on Monitoring and Assessment 2000 Guidelines on Monitoring and Assessment of Transboundary Rivers.
http://www.unece.org/env/water/publications/pub74.htm

United States Department of Agriculture (USDA) Cooperative State Research, Education, and Extension Service (CSREES) National Water Quality Program Principles in Water Quality Monitoring, Planning, and Restoration Venue: Asheville, NC
http://www.usawaterquality.org/

United States Department of Environment and Natural Resources Water Quality Monitoring Network
http://www.state.sd.us/denr/DES/Surfacewater/watermonitoring.htm

United States Environmental Protection Agency Monitoring Water Quality
http://www.epa.gov/owow/monitoring/index.html

United States Geological Survey National Water Quality Monitoring Council
http://water.usgs.gov/wicp/acwi/monitoring/

United Kingdom Environment Agency - Water Quality
http://www.environment-agency.gov.uk/subjects/waterquality/

Viet Nam: Water Quality Monitoring Network and Challenges
http://www.iges.or.jp/en/ltp/pdf/DHSon.pdf
http://bicn.com/wei/resources/BennettLai1996.htm

Watercheck: Water Quality in Europe's Recreational Waters
http://www.asrltd.co.nz/3rdFindlay.pdf

Water Quality Monitoring Technical Guide Book.
http://www.oweb.state.or.us/publications/mon_guide99.shtml

Water Quality Management
http://www.fwr.org/wqmgmt.htm

Water Quality Protection Guidelines for Mining and Mineral Processing Minesite Water Quality. Protection. No. 5. 2000
http://www.wrc.wa.gov.au/protect/policy/guidelines/G5_water%20quality.pdf

Water Quality Testing In South East Asia
http://www.idrc.ca/library/document/040700/

Water Technology Water Quality Monitoring
http://www.water-technology.net/contractors/monitoring/checklight/

WHO Guidelines for drinking-water quality
http://whqlibdoc.who.int/publications/9241545038.pdf

WHO Water Quality Monitoring
A practical guide to the design and implementation of freshwater quality studies and monitoring programmes.
http://www.who.int/water_sanitation_health/resourcesquality/wqmonitor/en/

WHO 1996 (Edited by J. Bartram and R. Balance) Water quality monitoring: A practical guide to the design and implementation of freshwater quality studies and monitoring programmes. ISBN 0-419-22320-7.

Wiley Design of Water Quality Monitoring Systems
http://www.wiley.com/WileyCDA/WileyTitle/productCd-0471283886.html

ABBREVIATIONS AND ACRONYMS

ACRONYM	DEFINITION
UNEP	United Nations Environmental Programme
WMO	World Meteorological Organization
UNESCO	United Nations Education, Scientific and Cultural Organization
WHO	World Health Organization
GEMS	Global Environment Monitoring System
UN	United Nations
QA/QC	Quality Assurance/Quality Control
NFP	National Focal Point
CFP	Collaborating Focal Point
MoU	Memorandum of Understanding
GRDC	Global Runoff Data Centre