Training Workshop on Water Monitoring Network and Early Warning System

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Water Monitoring Network

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

وَنَزَّلْنَا مِنَ السَّمَاءِ مَاءً مُبَارَكًا فَأَنْبَتْنَا بِهِ جَنَّاتٍ وَحَبَّ الْحَصِيدِ

"And We send down blessed rain from the sky, bringing forth gardens and grains for harvest"

[Al-Quran: Surah 50, Qaf, Ayah 9]

صَدَقَ اللَّهُ الْعَظِيمُ

INTRODUCTION

Water quality monitoring is routinely carried out for the following reasons:

- To establish baseline water quality conditions as part of the Environmental Impact Assessment, Appropriate Assessment, Assimilative Capacity Assessment and hydrological / hydrogeological impact assessment process;
- To ensure compliance with Industrial Emissions, Waste Permit/Licensing and Discharge Licensing requirements;
- To determine conditions prior to the commencement of construction, during construction and post construction;
- To aid in the preparation of source protection plans and drinking water compliance.

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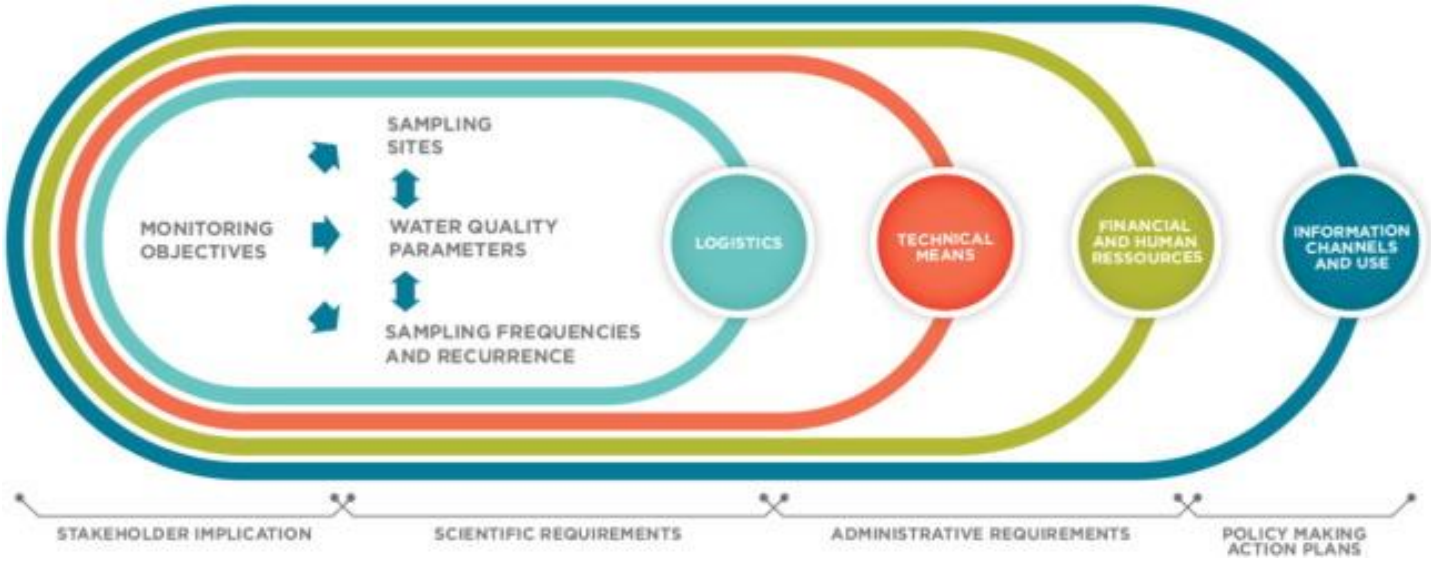
1. Concepts of Monitoring

A- Objectives of monitoring

- Setting up a monitoring programme requires a clear definition of the objectives, in order to avoid waste of time, efforts and money.
- “Need to know” and not “would be nice to know”
- Necessary information will depend on various “users” of water.



Difference between Water Quality Monitoring & Water Quality Assessment

Water Quality Monitoring: the collection of the relevant information on water quality

Water Quality Assessment: the overall process of evaluation of the physical, chemical and biological nature of the water

The reliable assessment of water quality through water quality monitoring programs is crucial in order for decision-makers to understand, interpret and use this information in support of their management activities aiming at protecting the resource.

B- Types of monitoring

1- MONITORING

Long-term, standardised measurement and observation of the aquatic environment in order to define status and trends

2- SURVEY

A finite duration, intensive programme to measure and observe the quality of the aquatic environment for a specific purpose

3- SURVEILLANCE

Continuous, specific measurement and observation for the purpose of water quality management and operational activities

4- Ambient monitoring

- Status and trend detection
- Testing of water quality standards
- Calculation of loads

5- Effluent monitoring

- Calculation and control of discharge standards
- Monitoring of plant performance

6- Early warning

- Warning for calamities
- Protection of downstream functions

7- Operational monitoring

Monitoring for operational uses such as irrigation, industrial use, inlets for water treatment works.

8- Single-objective monitoring

which may be set up to address one problem area only.

This involves a simple set of variables, such as:

- pH, alkalinity and some cations for acid rain
- nutrients and chlorophyll pigments for eutrophication
- Na, Ca, Cl and a few other elements for irrigation.

9- Multi-objective monitoring

which may cover various water uses and provide data for more than one assessment programme, such as drinking water supply, industrial manufacturing, fisheries or aquatic life, thereby involving a large set of variables.

C- Levels of water quality assessment

1- Simple monitoring

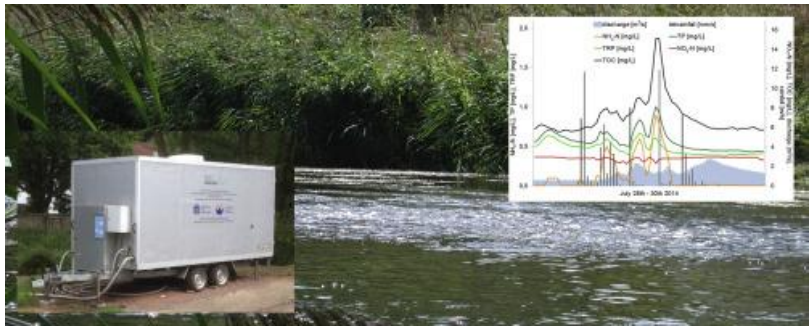
based on a limited number of samples, simple analysis or observations, and data treatment which can be performed by simple software

2- Intermediate-level monitoring

requiring more variables, stations, and specific laboratory equipment and PCs/software for data handling

3- Advanced level monitoring

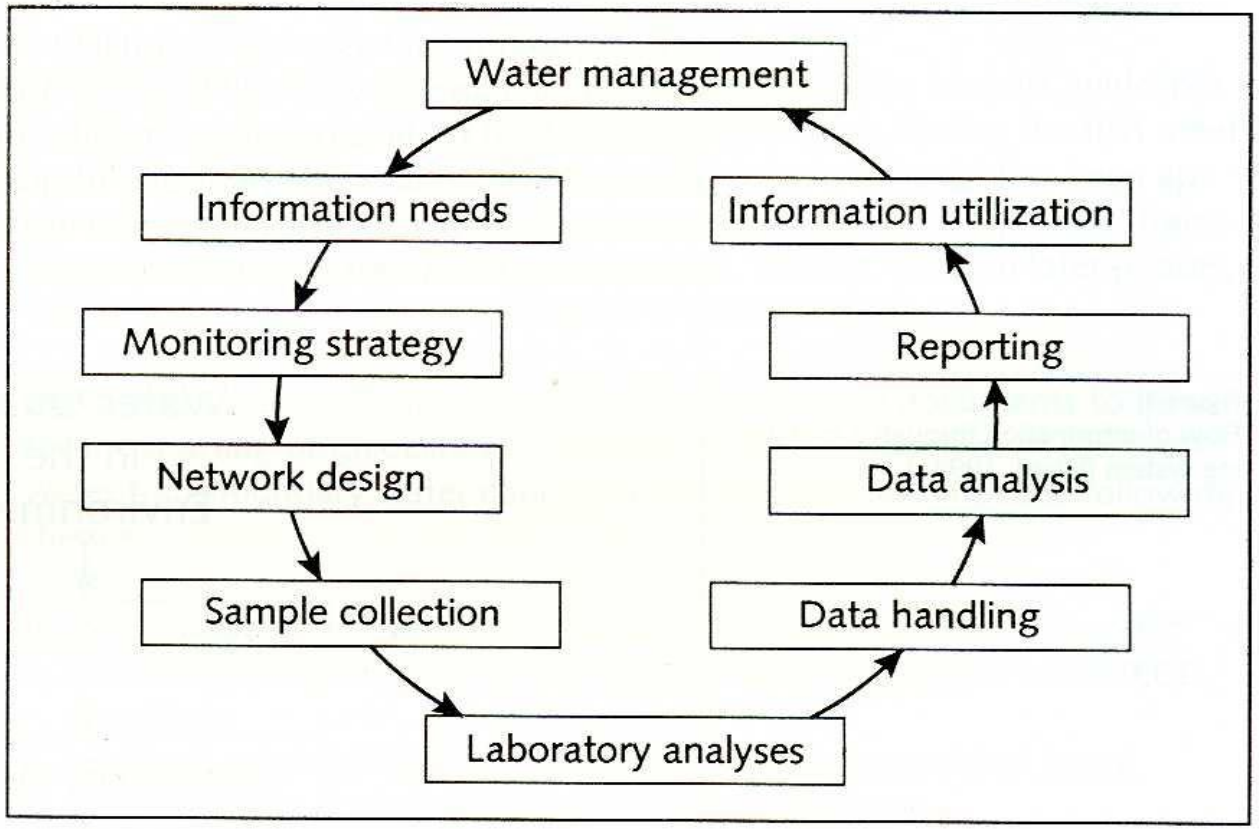
involving sophisticated techniques and highly trained technicians and engineers for sample analysis (*e.g.* micropollutants) and data handling, often using mainframe computer systems.



D- The monitoring cycle

1:“what do you want to know?”

2: “how to find out”



5:“feed-back; changes”

4:“evaluation”

3: “the real field and labwork”

E- Key elements of an assessment programme

1: Appropriate objectives

These should take into account the hydrological factors, the water uses, the economic development, the legislative policies etc. Necessary decisions involve whether the emphasis should be put on concentrations or loads, or spatial or time distributions, and the most appropriate monitoring media.

2: Preliminary surveys

These are short-term, limited activities to determine the water quality variability, the type of monitoring media and pollutants to be considered, and the technical and financial feasibility of a complete monitoring programme.

Study Area in the Preliminary survey

Clear description of the study area should be made:

- Definition of the area, and schematisation in clear, not-overloaded maps
- A summary of the environmental conditions and processes, including human activities, such as population, land use, industries, hydraulic structures, (ground)water extraction sites and recreational areas
- Meteorological and hydrological information, including hydrographs of river flows, and precipitation/evaporation data at stations **as close as possible** to the water course
- A summary of actual and **potential** water uses (5 year horizon).

3: Monitoring design

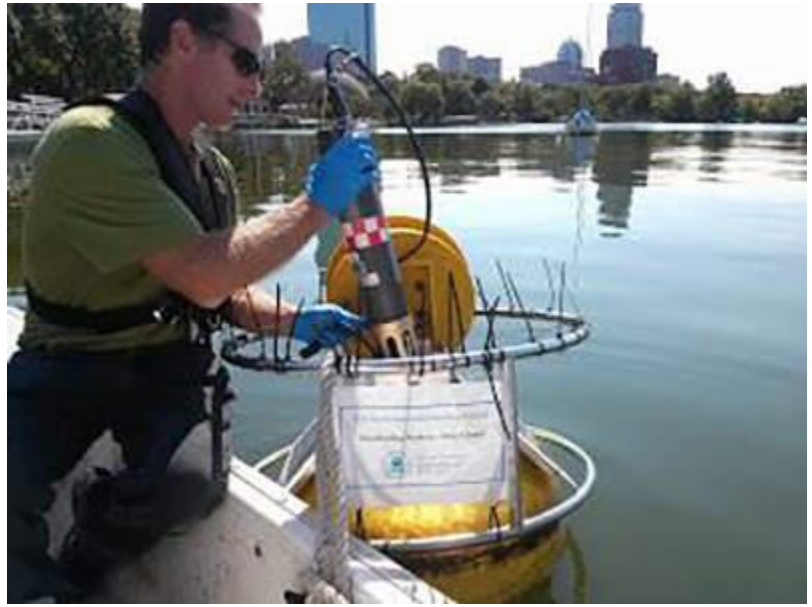
This includes the selection of types of pollutants, station location, sampling frequency, sampling apparatus, etc.

4: Field monitoring operations

These include *in situ measurements, sampling of appropriate media* (water, biota, particulate matter), sample pretreatment and conservation, identification and shipment.

5: Hydrological monitoring

This includes water discharge measurements, water levels, thermal profiles, etc., and should always be related to the water quality assessment activities.



6: Laboratory activities

These include concentration measurements, biological determinations, etc.

7: Data quality control

This must be undertaken by using analytical quality assurance within each laboratory, and amongst all laboratories participating in the same programme, and by checking field operations and hydrological data.

8: Data storage treatment and reporting

This is now widely computerised and involves the use of databases, statistical analysis, trend determinations, multi-factorial correlation, etc., and presentation and dissemination of results in appropriate forms (graphs, data disks, *etc*.).

9: Data interpretation

This involves comparison of water quality data between stations (water quality descriptors, fluxes), analysis of water quality trends, development of cause-effect relationships between water quality data and environmental data (geology, hydrology, land use, pollutant sources inventory), and judgement of the adequacy of water quality for various uses *etc.*

For specific problems, and the evaluation of the environmental significance of observed changes, external expertise may be needed.

Publication and dissemination of data and reports to relevant authorities, the public, and the scientific community is the necessary final stage of assessment activities.

10: Water management recommendations

These decisions should be taken at various levels from local government to international bodies, by water authorities as well as by other environmental authorities. An important decision is the re-design of assessment operations, to improve the monitoring programme and to make it more cost-effective.

2- River Basin Monitoring

- River Basin monitoring system helps to control rivers, lakes, reservoirs, wetlands, groundwater,…. It is capable to control their hydrological, hydrochemical and other characteristics (i.e. their hydrological regime) in real-time mode.
- The monitoring system takes into account factors not only anthropogenic or related to water pollution, but also natural, because they have also strongly influence for the socio-economic and environmental conditions of the water body and waterside.
- The observation system consists of ground (both stationary observations at hydrological posts and expeditionary) and remote (including aeronautical and satellite); a system of continuous (current) and integrated monitoring of the condition of water resources, monitoring and recording quantitative and qualitative characteristics at different time, interdependent influence and changes in consumer properties, as well as a system for forecasting the preservation and development in different modes of use.

A- Importance of Rivers

Lifelines of Humanity

→Cradle of mankind between Euphrate and Tigris

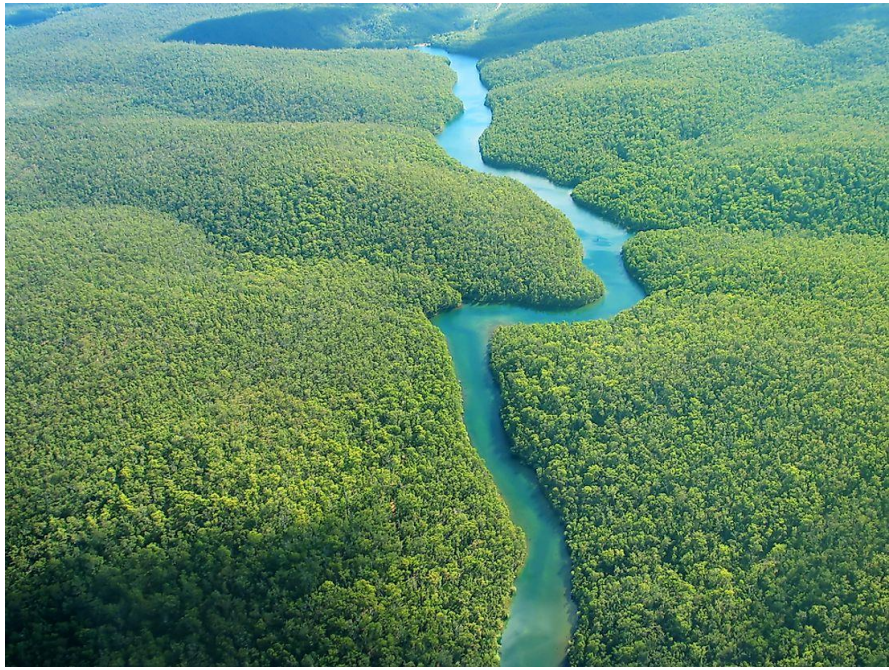
→Importance of the river Nile in ancient Egypt

→Yangtze River and its importance for China

→Spiritual, cultural and economic values of the River Ganghes in India

→Amazon River in South America

→Etc!



Why?

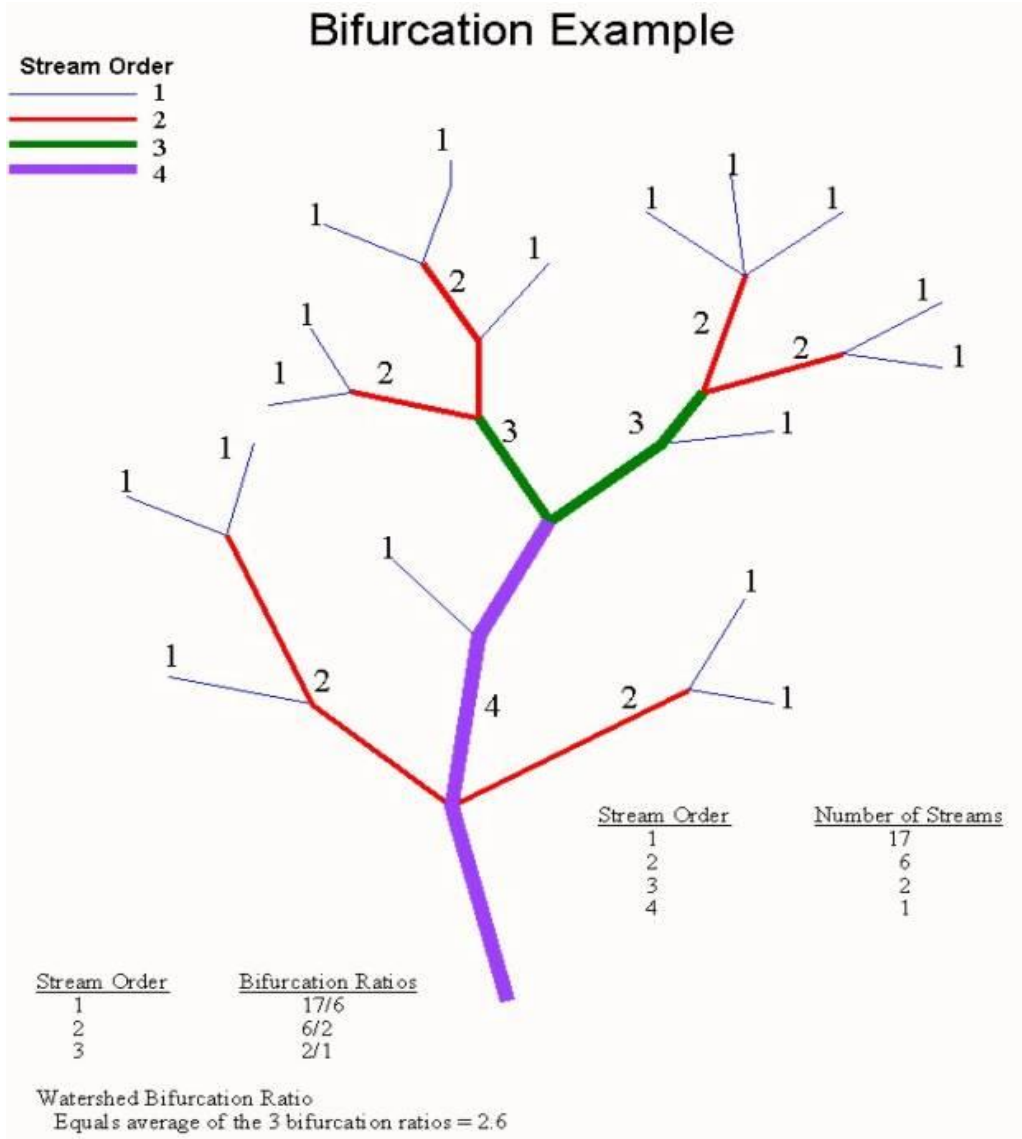
- Drinking water
- Agriculture – Irrigation or flooding
- Industrial uses
- Wildlife habitats – Fishing and Hunting
- Recreational and Aesthetic uses

B- General characteristics of rivers

Bifurcation-Stream Order

Lower order streams have
- less tributaries
- little width and depth
- allochtonous nutrient inputs

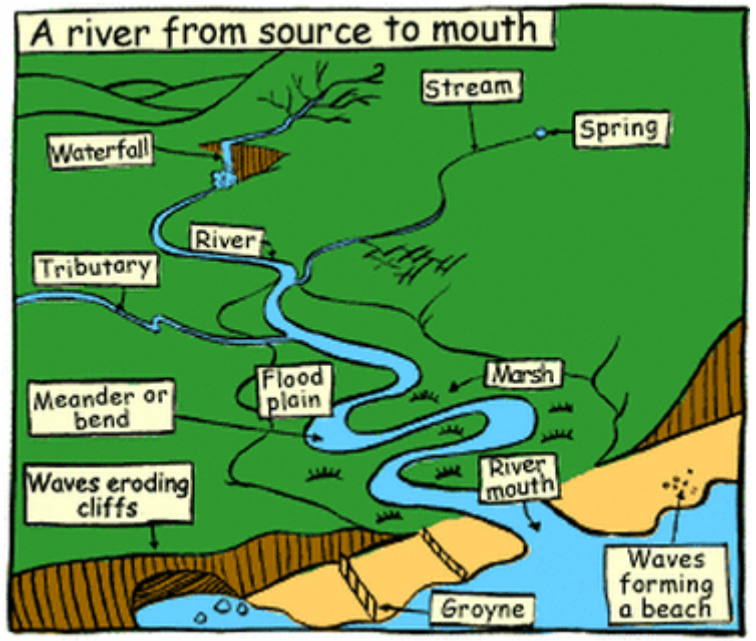
Higher order streams have
- more tributaries
- larger width and depth
- allochtnous AND autochtonous production

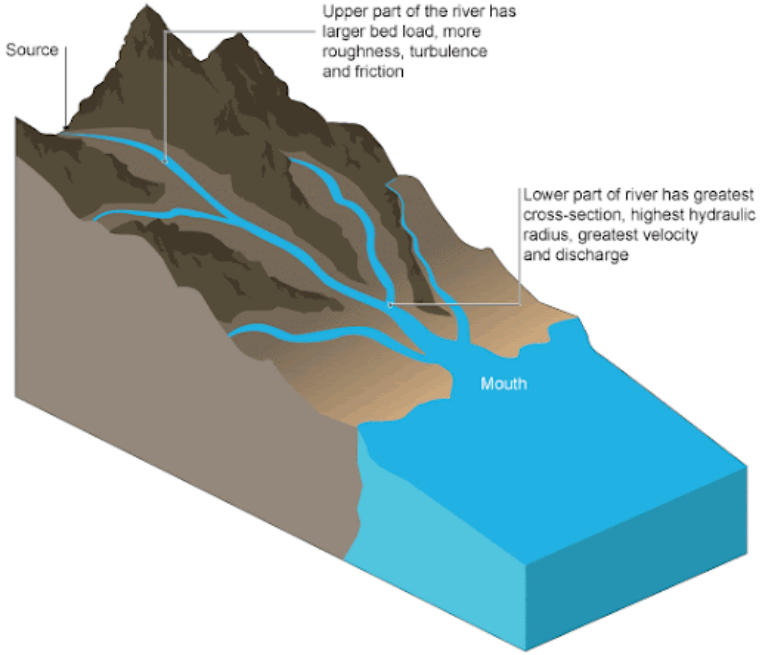


Rivers - Source To Mouth

Having understood the basics of a Drainage Basin we now need to consider the journey that a river within a Drainage Basin takes from its beginning to its end. The path the river follows from its source to mouth is known as the river's course.

When studying rivers we often divide it into 3 main sections, the upper course; middle course and lower course. Each part of the river has distinctive features which form and the characteristics of the river and its surrounding valley change downstream.





Some examples of how the landscape changes along the course of a river.

Upper Course

Characteristics

* Steep / V-shaped Valley
* Narrow / Shallow Channel
* High Bedload

Features

* 'V' Shaped Valleys
* Interlocking Spurs
* Waterfalls
* Gorges

Middle Course

Characteristics

* Open / gentle sloping valley with floodplain
* Wider / deeper Channel
* More suspended sediment

Features

* Meanders
* River Cliffs
* Slip off Slopes

Lower Course

Characteristics

* Open / gentle sloping valley with floodplain
* Flat & Wide Floodplain
* Wide, open valley
* Very wide and very deep channel

Features

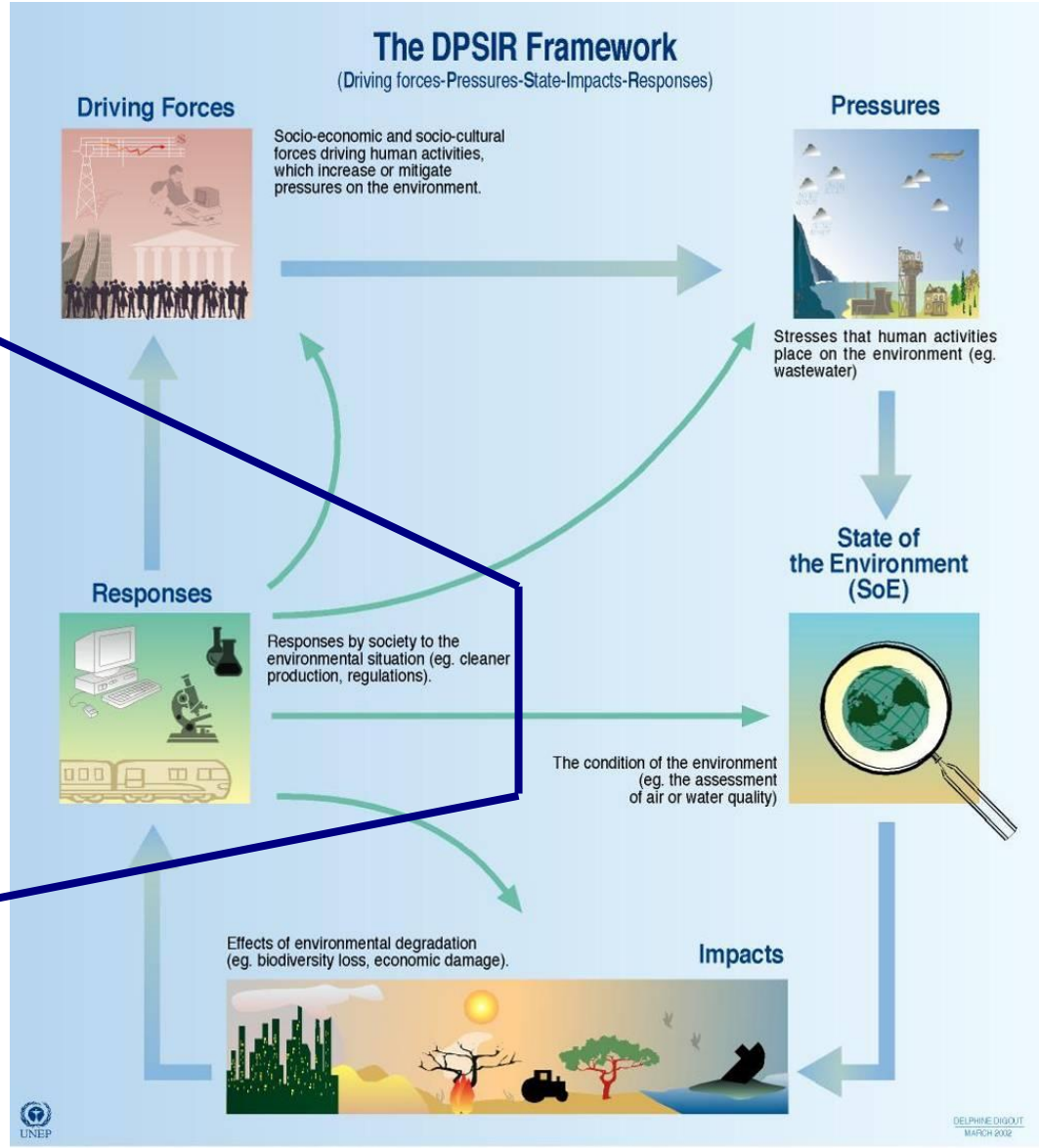
* Ox-bow Lakes
* Flood Plains
* Levees

C- Basic things to keep in mind in Monitoring of Rivers

- Why monitor?
  - water quality and quantity necessary to sustain
    - aquatic life
    - human life
- How to select monitoring stations?
    - Rather riffles than pools
    - If possible in a uniform straight stretch
    - preferably upstream or sufficiently downstream from confluences or obstacles (*i.e.* bridges)

The DPSIR Framework
(Driver-Pressure-State-Impact-Response Framework)

Water Quality Management



Source : Global International Water Assessment (GIWA), 2001; European Environment Agency (EEA), Copenhagen.

Water Quality Monitoring And Assessment

The framework is seen as giving a structure within which to present the indicators needed to enable feedback to policy makers on environmental quality and the resulting impact of the political choices made, or to be made in the future.

Sites Selection

After having set the **objectives:**

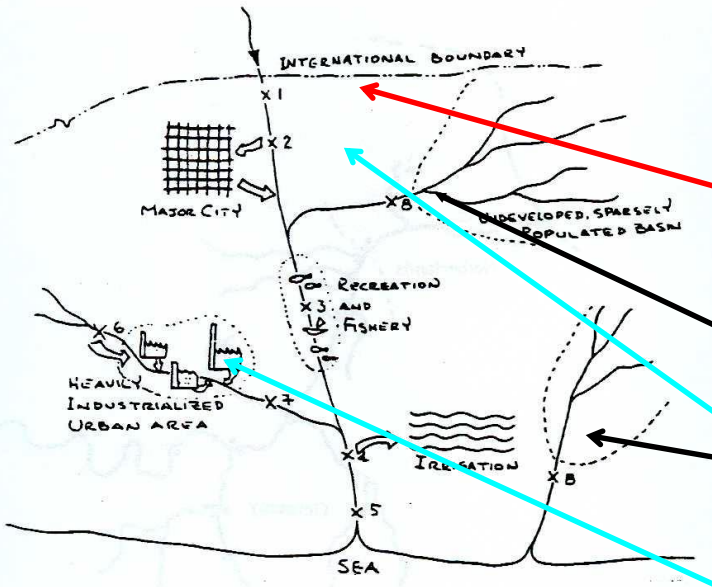
***Macro*location** of the stations such as:

- Background or baseline stations
- State/district boundaries
- Impacts of major pollution loads (cities, industries, irrigation areas…)
- Recreational areas

***Micro*location**, with **exact** position monitoring site:

- *Usually* after complete mixing of the river
- Sites with guaranteed accessibility (*e.g.* at bridges)

Choose stations



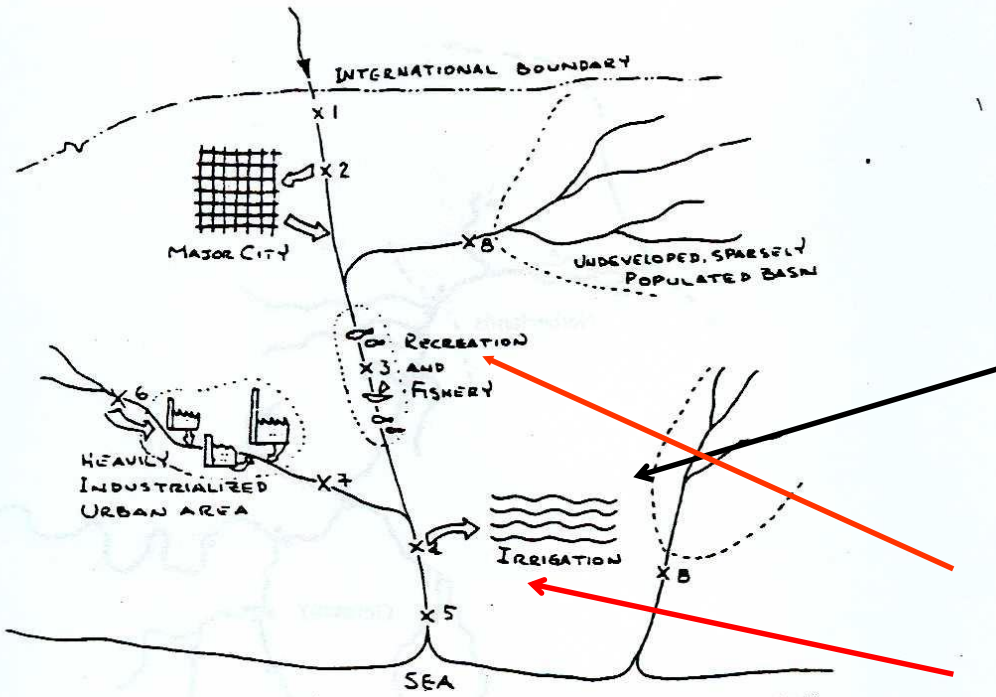
Monitoring site selection - Rivers

Station	Type	Criteria
1	impact (or baseline)	immediately downstream of an international boundary
2	impact	abstraction for public supply of large town
3	impact	important fishing, recreation and amenity zone
4	impact	abstraction for large-scale agricultural irrigation
5	trend	fresh water tidal limit of major river
6	impact	abstraction for large industrial supply
7	impact	downstream of industrial effluent discharges and important tributary influencing main river
8	baseline	station where water is in a natural state (no direct or indirect pollution; no water use)

At the border (country, district)

- Background stations for natural water quality

- Impact stations: before/after industries, cities,……. Also: effluent monitoring for industries



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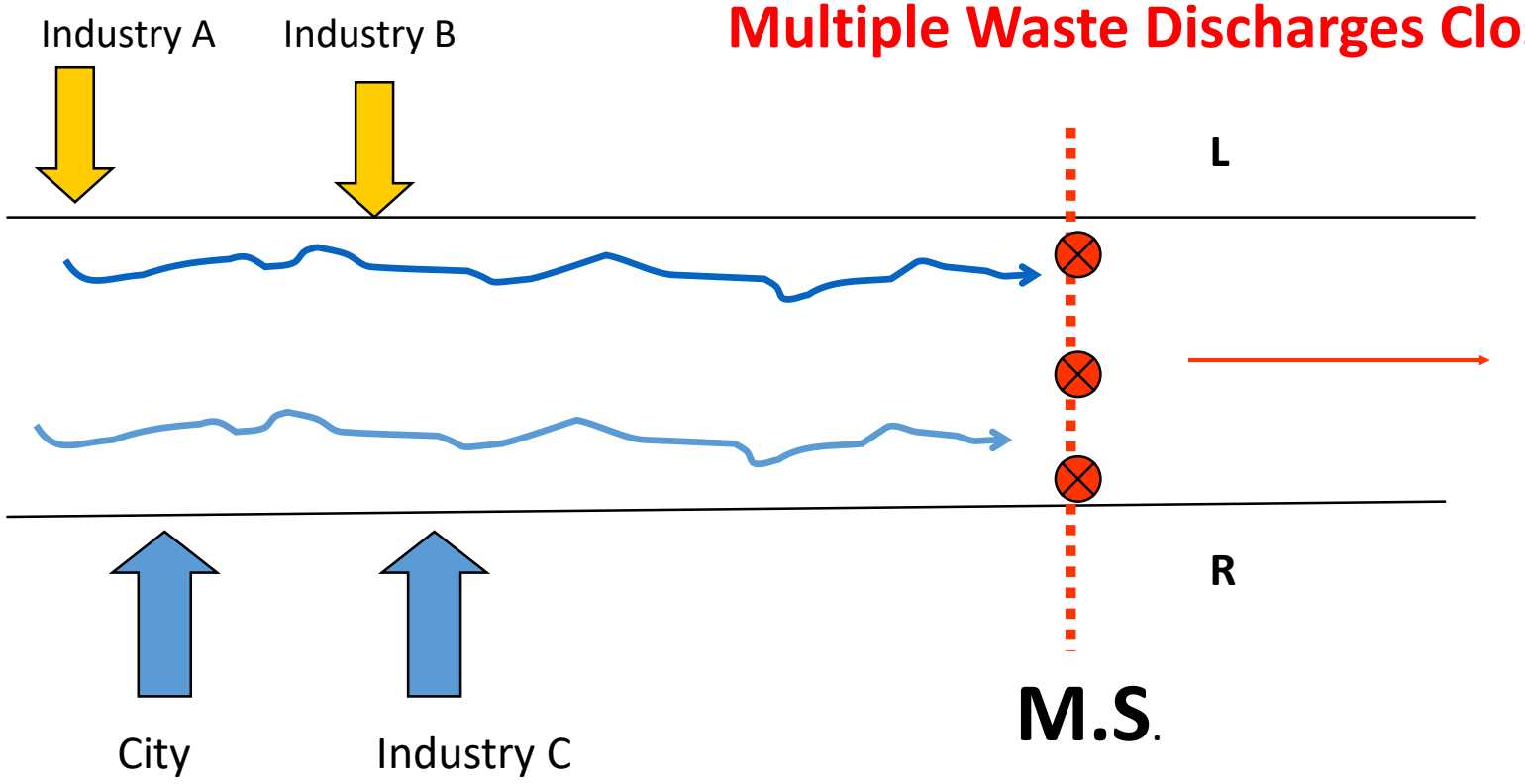
- Impact irrigation areas
- Control of environmental objectives (nature, swimming; seawater intrusion,..)

Multiple Waste Discharges Close Together



- Choose monitoring station M.S. downstream of “clustered” discharges

- Since waste streams not yet fully mixed, it is possible to recognize “fingerprints”of the individual discharges at M.S.

Example:

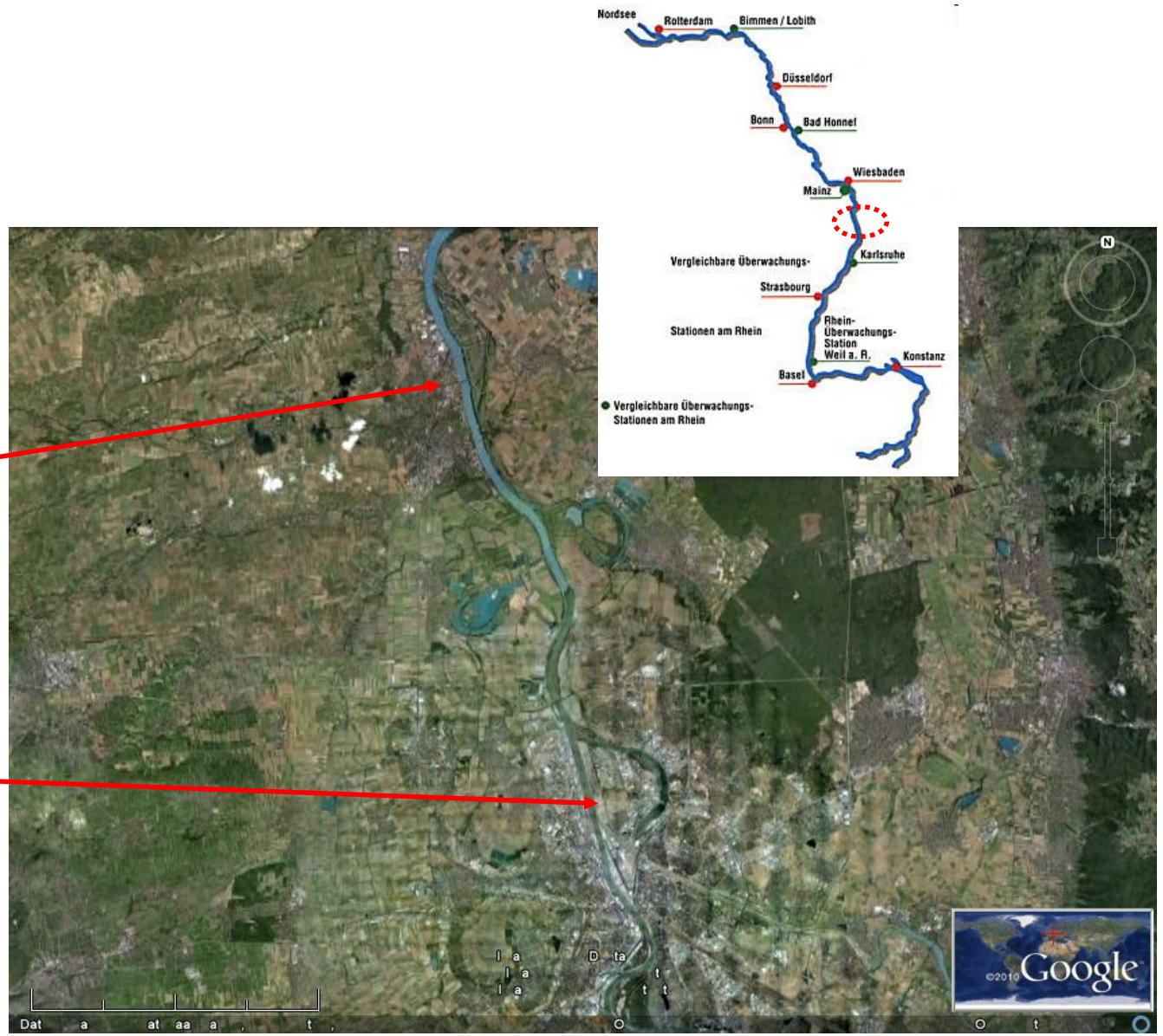
River Rhine monitoring station "Worms" (Germany); river flows S→ N

- Some 15 km downstream of main industrial zone Mannheim (BASF, ...)
- Water quality on left, right bank, and two in the middle of river Rhine.

Equipment:

- Online: T, DO, EC, pH, turbidity..
- Photometers, GC/MS..
- Biotests (daphnia, algae);
- Etc.

Industrial zone



Self-monitoring Industries

- Under strict control and enforcement by the regulatory body

- Can be of the discharger's own interest (valuable information about production efficiencies, *etc.)*

- Discharge permit can regulate:
Maximum amount of pollutants' discharges (**emission)** and
Maximum input **into environment (immision)**

- This approach common practice in *e.g.* The Netherlands

3- Recent Developments in Water Quality Monitoring

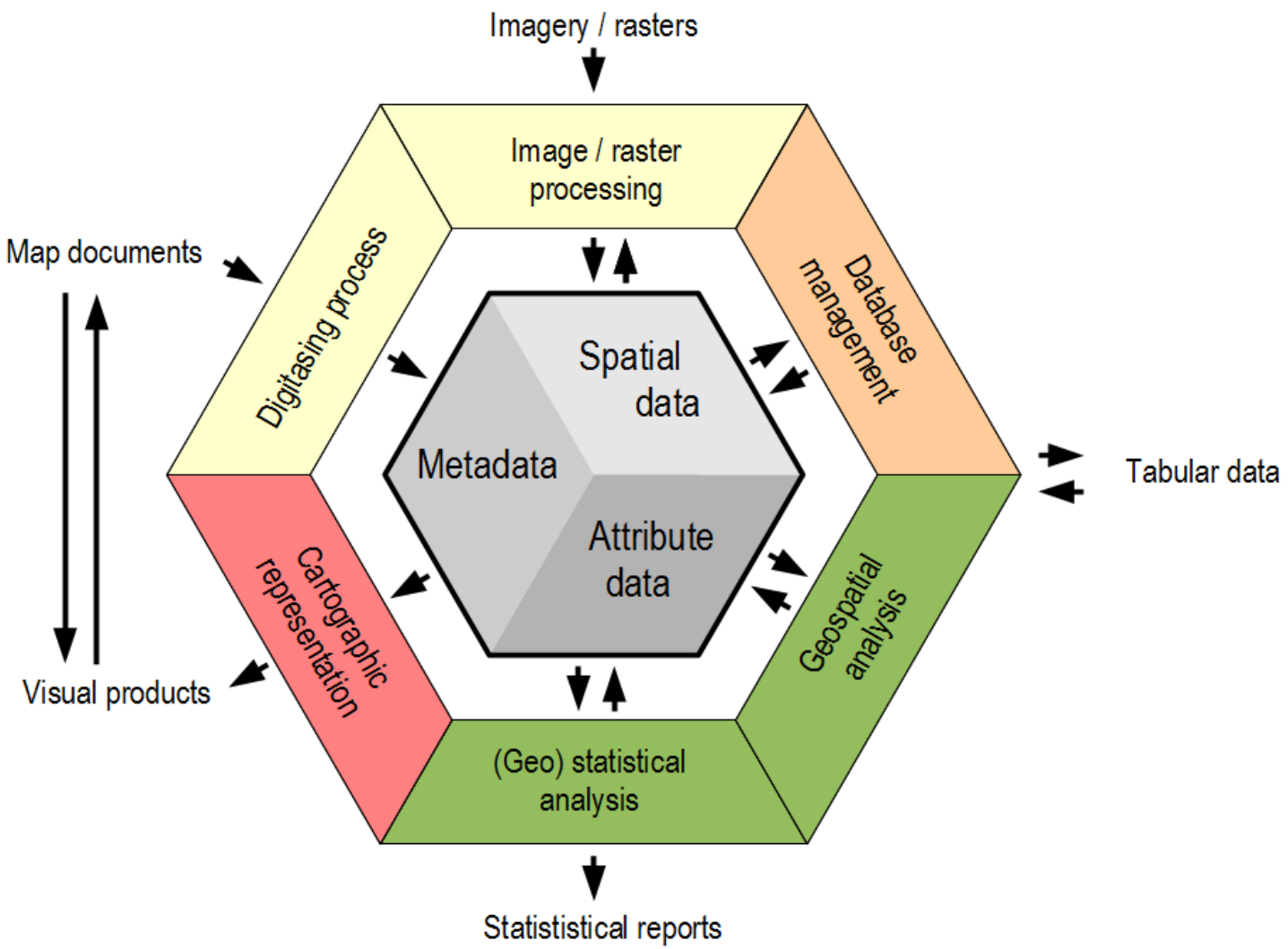
A- Remote sensing; GIS; Water quality modelling

- Remote sensing: making use of airplanes, satellites for *e.g.* monitoring plankton blooms; turbidity in lakes, oceans
- GIS: make "overlays" with water quality, land use, geology….
- Water quality modelling (e.g. for early warning monitoring)
- GIS as a separate tool: data processing, model output visualisation.
- Tightly integrated with modelling system: as an important component, e.g., ArcSWAT, MIKE SHE, HEC-RAS, HydroGeoAnalyst, etc

Remote Sensing

- Remote sensing can be defined as the collection of data about an object from a distance. Humans and many other types of animals accomplish this task with aid of eyes or by the sense of smell or hearing. Geographers use the technique of remote sensing to monitor or measure phenomena found in the Earth's lithosphere, biosphere, hydrosphere, and atmosphere.
- Remote sensing of the environment by geographers is usually done with the help of mechanical devices known as remote sensors. These gadgets have a greatly improved ability to receive and record information about an object without any physical contact. Often, these sensors are positioned away from the object of interest by using helicopters, planes, and satellites. Most sensing devices record information about an object by measuring an object's transmission of electromagnetic energy from reflecting and radiating surfaces.
- Remote sensing imagery has many applications in mapping land-use and cover, agriculture, soils mapping, forestry, city planning, archaeological investigations, military observation, and geomorphological surveying, among other uses.

GIS


Imagery / rasters
Image / raster processing
Digitasing process
Database management
Map documents
Spatial data
Metadata
Attribute data
Tabular data
Cartographic representation
Geospatial analysis
Visual products
(Geo) statistical analysis
Statististical reports

Water quality modeling

- **Water quality modeling** involves water quality based data using mathematical simulation techniques. Water quality modeling helps people understand the eminence of water quality issues and models provide evidence for policy makers to make decisions in order to properly mitigate water. Water quality modeling also helps determine correlations to constituent sources and water quality along with identifying information gaps.
- Due to the increase in freshwater usage among people, water quality modeling is especially relevant both in a local level and global level. In order to understand and predict the changes over time in water scarcity, climate change, and the economic factor of water resources, water quality models would need sufficient data by including water bodies from both local and global levels.
- A typical water quality model consists of a collection of formulations representing physical mechanisms that determine position and momentum of pollutants in a water body. Models are available for individual components of the hydrological system such as surface runoff; there also exist basin wide models addressing hydrologic transport and for ocean and estuarine applications.

B- High-Resolution Nutrient Sensors

- High-Resolution Nutrient sensors deliver continuous nutrient measurements that provide unique insights into the coupling of hydrological, geochemical, and biological processes. From lakes and rivers to deep oceans, continuous monitoring of nutrients is increasingly being used to understand ecosystem dynamics at time scales that capture daily processes, trends and events.
- Technology developed for oceanic systems is increasingly applied to freshwater systems, especially in Great Lakes, but also in river systems.

The HydroCycle-PO4 is a wet-chemical sensor engineered for environmental monitoring to enable valid, scientifically defensible results that lead to better management recommendations. It is ideally suited for monitoring point and non-point source nutrient inputs and environmental dynamics and change. The HydroCycle-PO4 is intended for continuous or real-time measurement of dissolved phosphate :Lakes and reservoirs, Streams, rivers, channels, and canals, Estuaries, Coastal oceans

Example : SUNA V2 Nitrate Sensor

- The SUNA V2 is the ultimate solution for real-time nutrient monitoring. This sensor measures nitrate with industry leading accuracy and stability over a wide range of environmental conditions (including extremely turbid and high CDOM conditions), from blue-ocean nitraclines to storm runoff in rivers and streams.
- The SUNA V2 incorporates the proven MBARI-ISUS nitrate measurement technology, which is based on the absorption characteristics of nitrate in the UV light spectrum.

NO_3 Sensor

SUNA UV Nitrate Sensor

What are the characteristics of a NO_3 sensor?
What kind of applications is this appropriate for?

Accuracy: ±0.028 mg/l (± 2 µM) or ± 10 of reading, whichever is greater

Detection range: 0.007 to 28 mg/l-N (0.5 to 2000 µM)

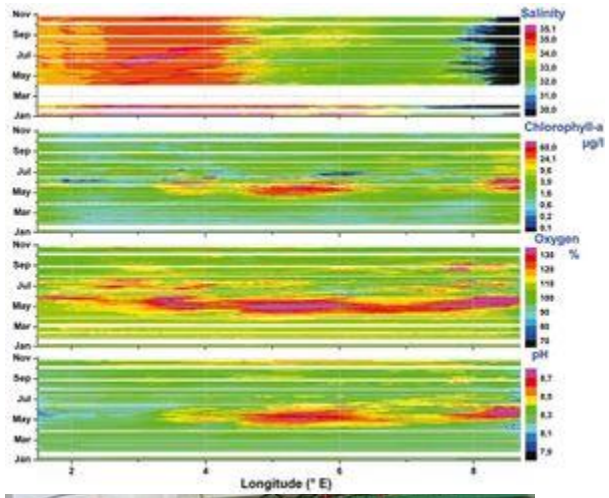
Applications:

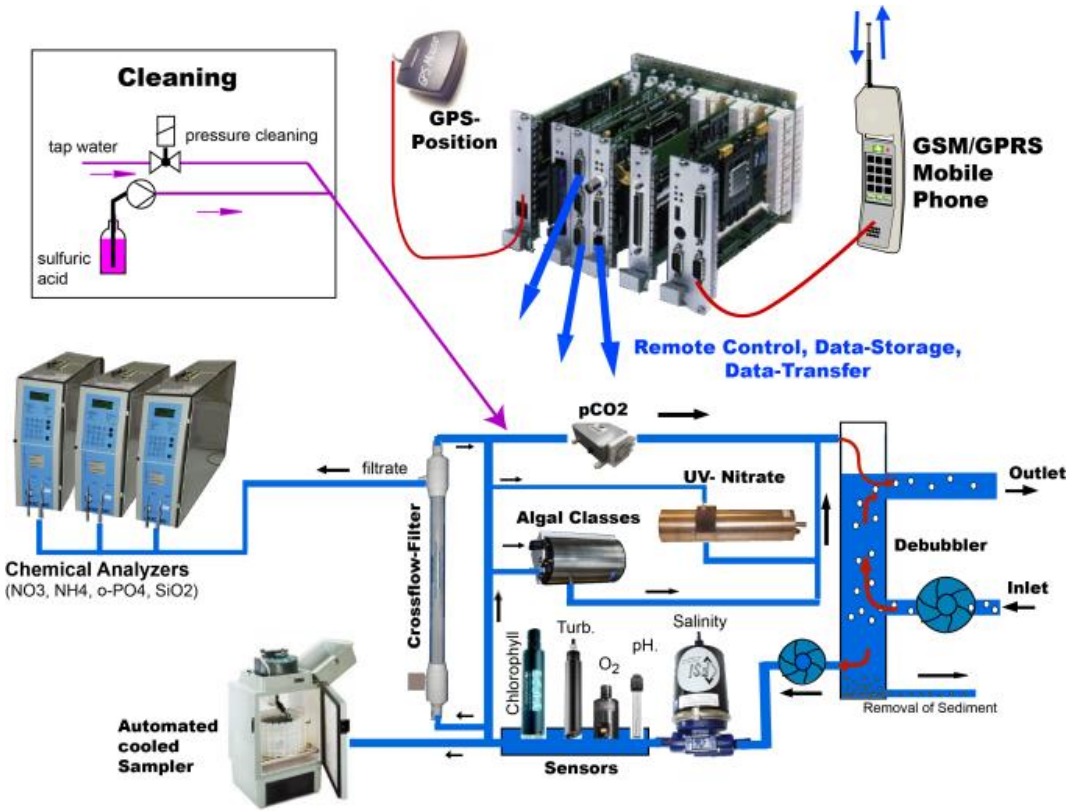
- Long term nitrate monitoring
- Water quality assessment in estuaries and coastal environments
- Freshwater nutrient loading studies
- Watershed TMDL assessment
- Phytoplankton bloom prediction
- Wastewater monitoring

The SUNA UV nitrate sensor is the ultimate chemical-free solution for autonomous monitoring of nitrate concentrations in ocean, estuarine and freshwater environments.

C- Ferry Boxes

- Continuous and automatic water quality observations along transects
- Equipment mounted on ferry boats, to continuously monitor *e.g.* salinity, water temperature, oxygen, pH, turbidity, Chlorophyll-a, Nutrients, etc.





D- Online Water Quality Monitoring in Source Water

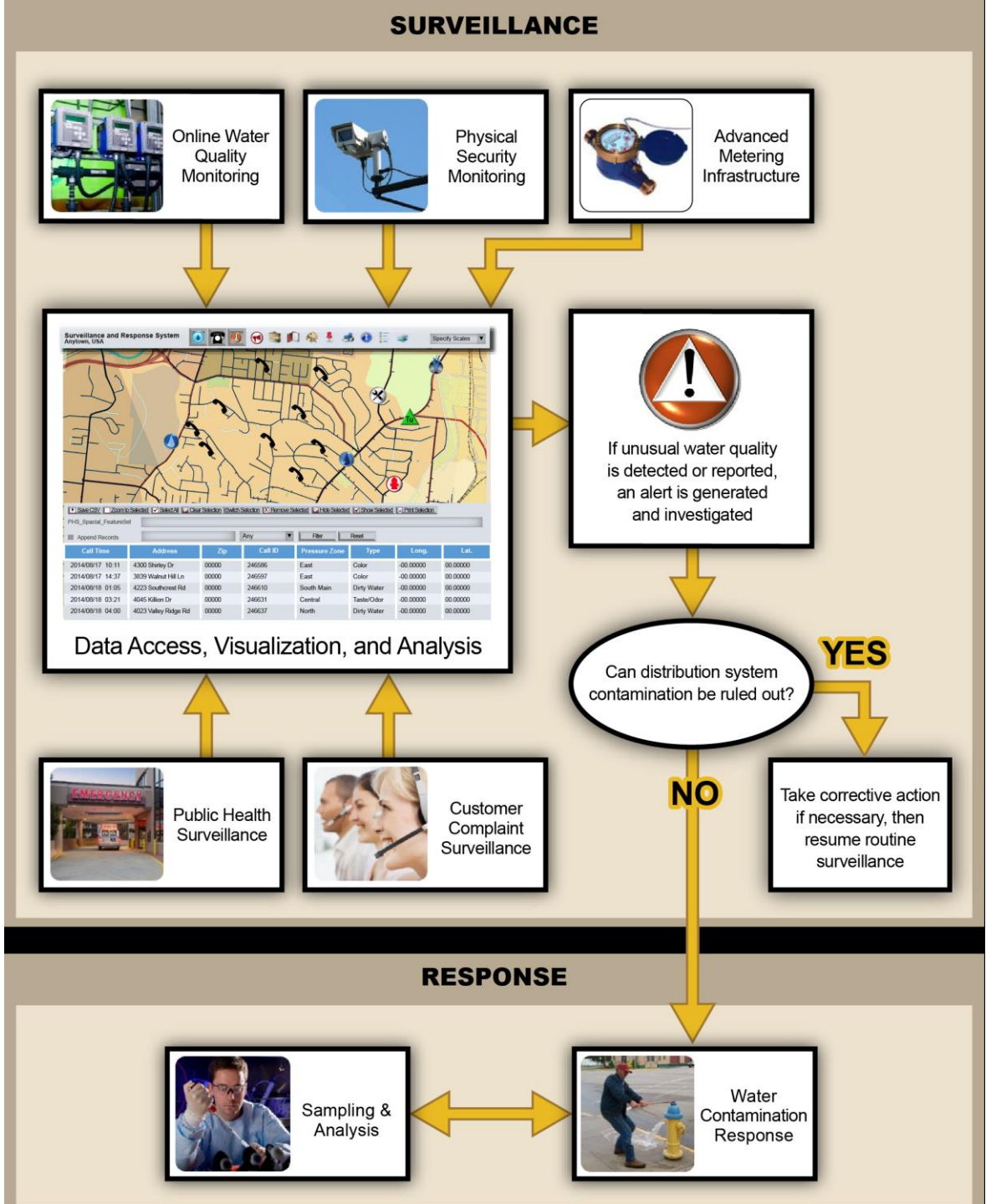
- Online Water Quality Monitoring in Source Water (OWQM-SW), involves the use of online ***water quality instruments*** for ***real-time*** measurement of water quality in a source water. The understanding gained through OWQM-SW enables drinking water utilities to more efficiently treat the source water, identify significant changes in water quality, implement appropriate treatment strategies, and take actions to protect the source water for its intended use.
- OWQM-SW can be implemented as a stand-alone monitoring program, or it can be incorporated into a ***Water Quality Surveillance and Response System*** (SRS). An SRS is a framework developed to support monitoring and management of water quality from source to tap. The system consists of one or more ***components*** that provide information to guide drinking water utility operations and enhance a utility's ability to quickly detect and respond to water quality changes.

Incorporation of OWQM-SW into an SRS

The design of an SRS is flexible and can include any combination of components shown. However, it is recommended that all SRS designs include at least one surveillance component and basic capabilities for ***Sampling and Analysis*** (S&A) and ***Water Contamination Response*** (WCR).

S&A is important because the surveillance components of an SRS, including OWQM-SW, typically provide only a general indication of a potential water quality problem; S&A establishes capabilities for confirming or ruling out specific contaminants or contaminant classes.

WCR establishes procedures and relationships with response partners for responding to serious water quality problems such as contamination.



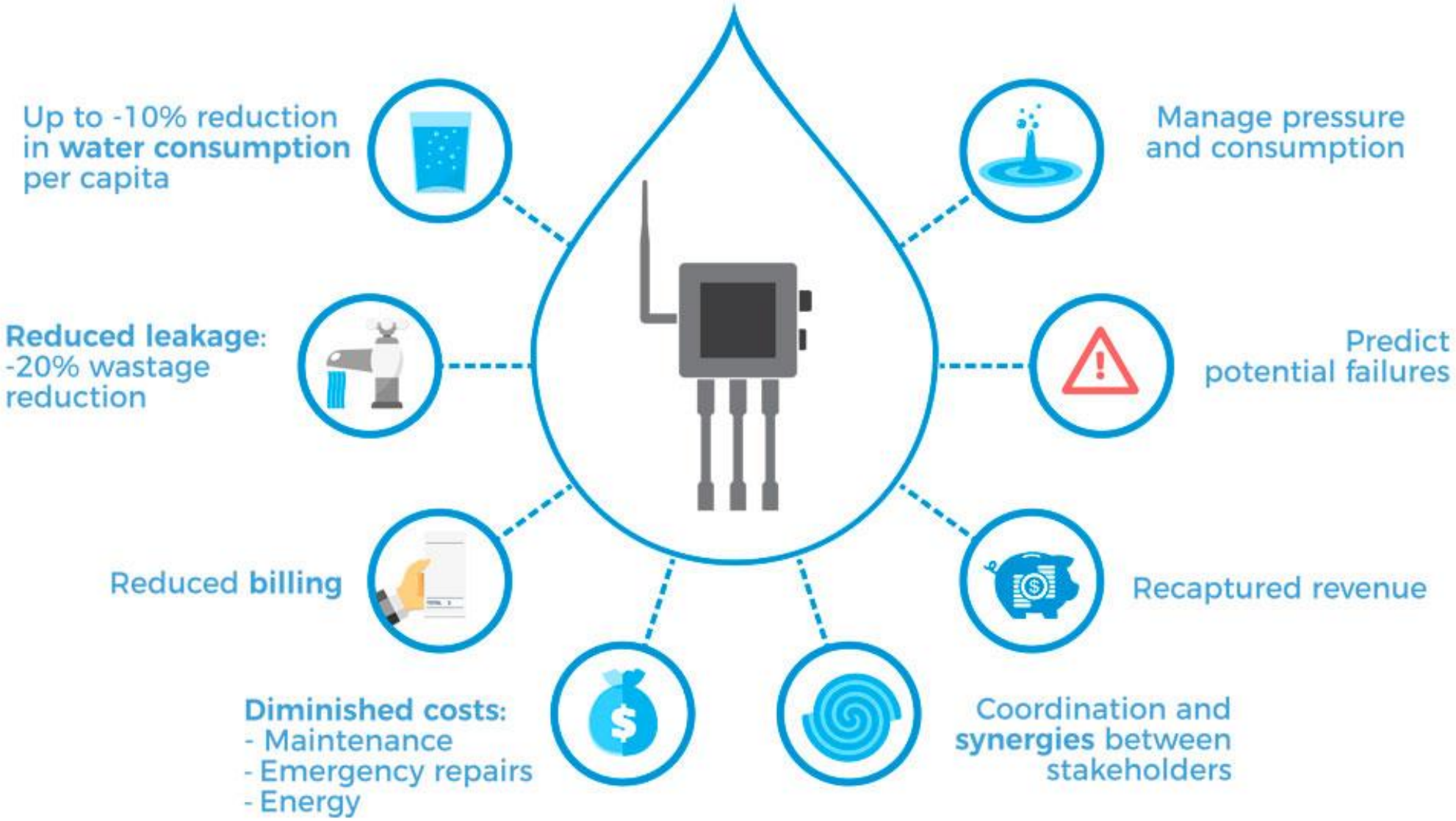
Smart Water IoT solutions to fight against climate change and scarcity

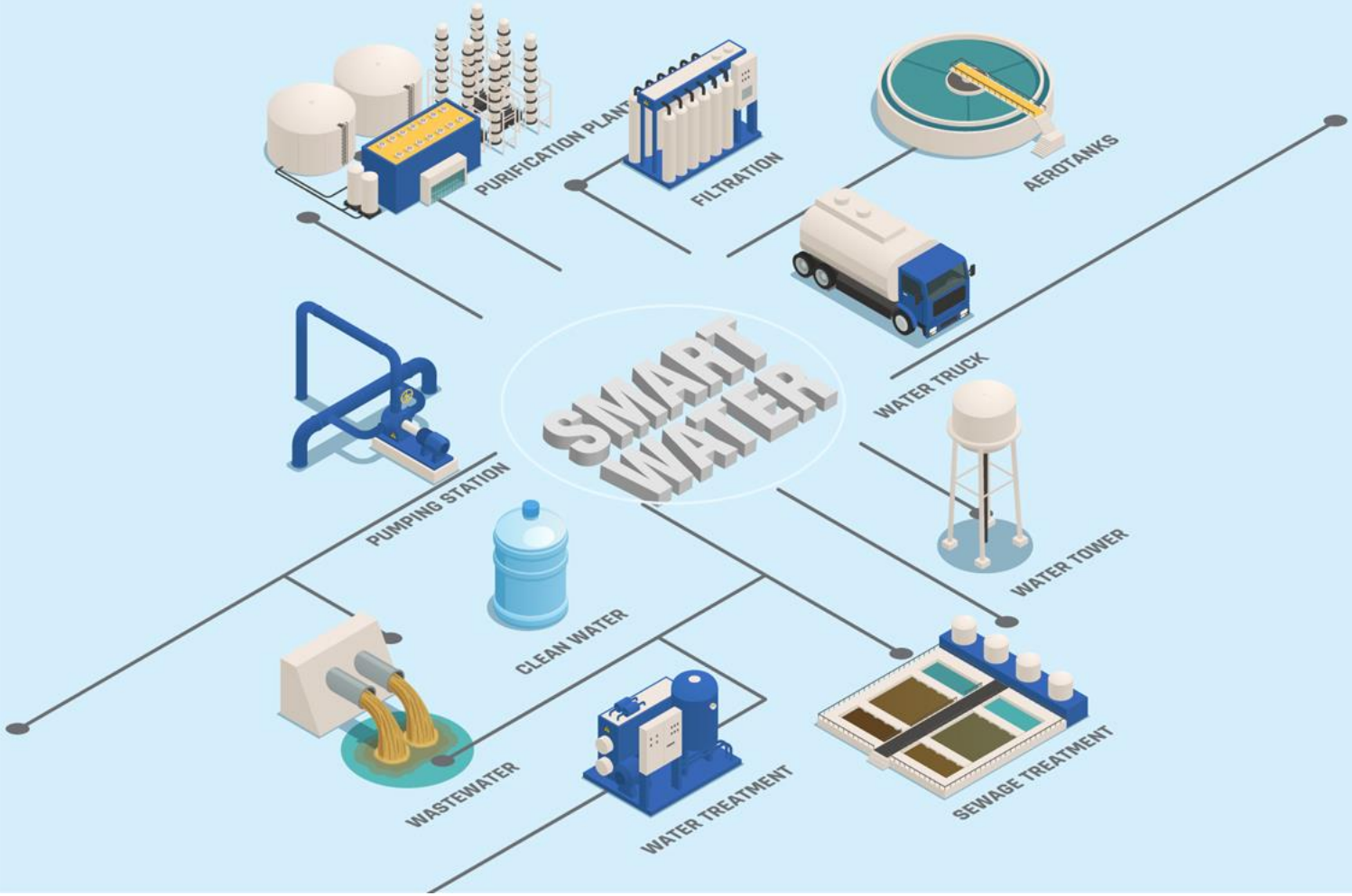
Water scarcity enforces humankind to find new ways of smart water management. 2.1 billion people do not have access to clean and safe drinking water at home, and there are huge inequalities between countries. Water demand is expected to increase by 1/3 by 2050, since climate change and population growth are the main challenges for water.

Internet of Things (IoT) can help to improve water management issues such as consumption, water usage improvement and cost reduction.

A new model of IoT platform for Smart Water quality control includes performance sensors for applications such as potable water monitoring, fish farm management, chemical leakage detection, remote measurement of swimming pools and spas, and seawater pollution.

BENEFITS OF SMART WATER SOLUTIONS

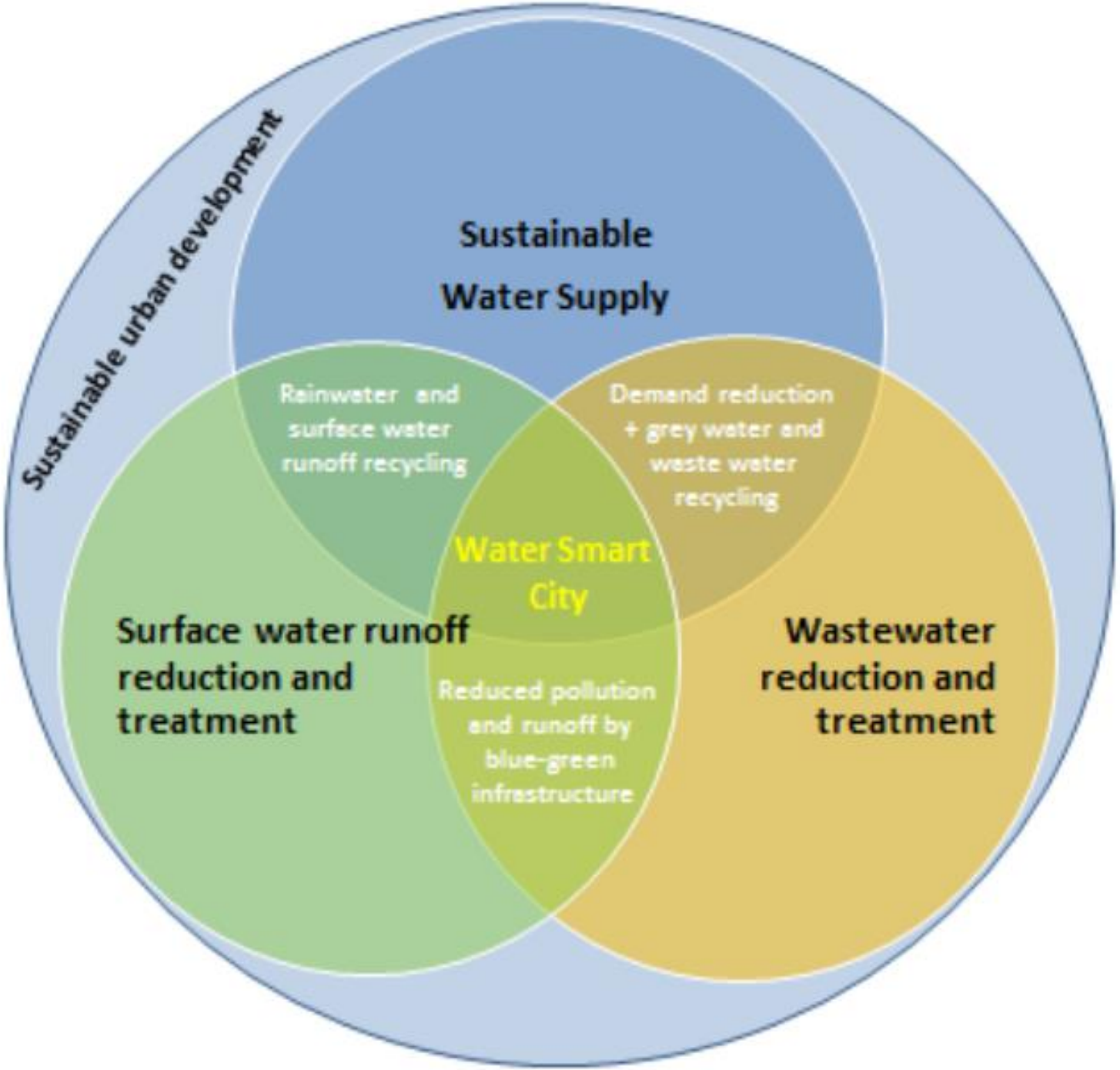




SMART WATER

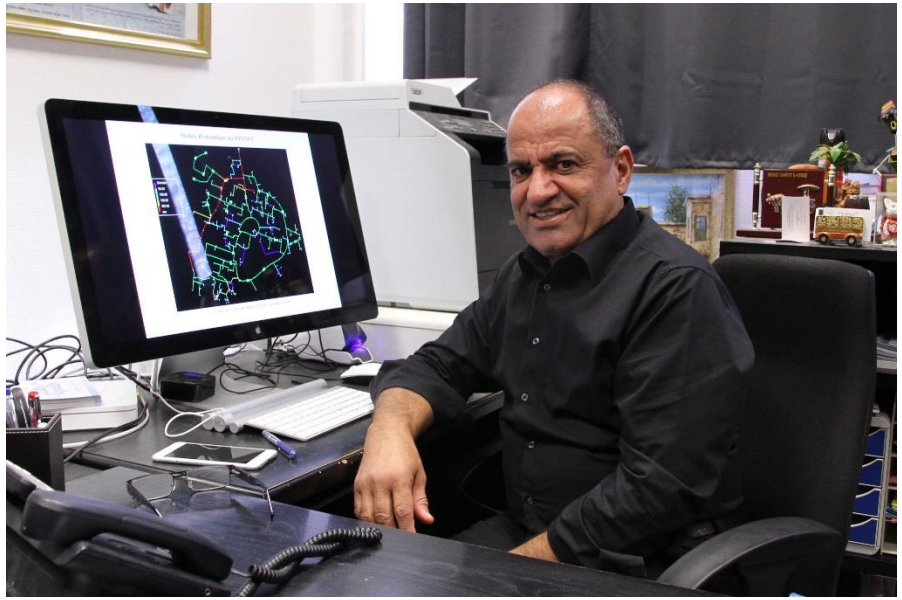
Digital Solutions for Citizen Services Integrated Water, Waste water and Storm water Management system.

Water Smart City approach is a visionary approach to integrate sustainable urban planning and water management that aims to minimise the hydrological impacts of urban development on the surrounding environment.



Use of the smart technology for water quality control

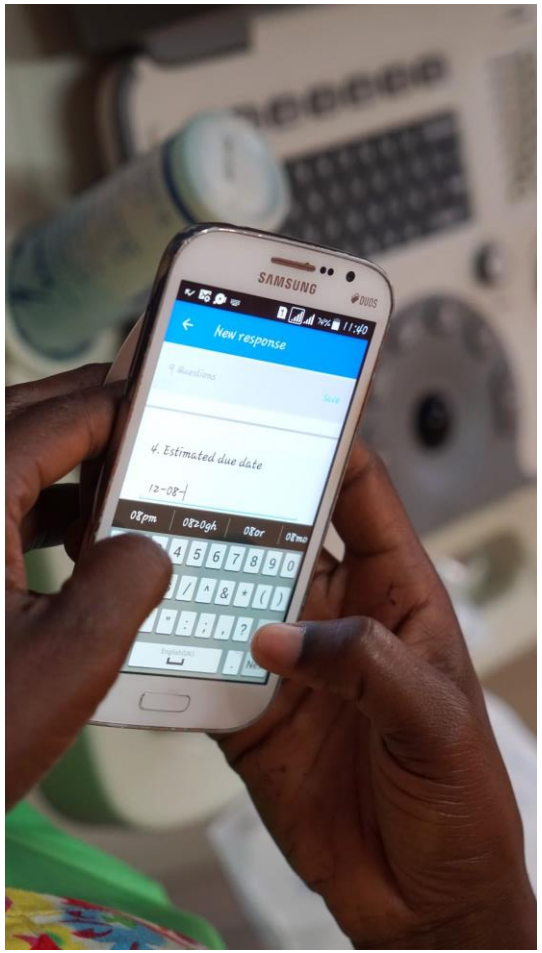
- Pioneer : Professor Isam SHAHROUR, Lille University – France
- He developed the concept of the Smart Water System (smart sensors, data collection, data analysis,..) through the project **SunRise Smart City**, which consists of building a large-scale model of the smart city.



He conducts various smart city projects with local authorities and companies. Pr Shahrour has written more than 120 papers for journals and he is regularly invited to give academic and public keynotes on issues related to the smart city, sustainable city and resiliency.

Mobile Phones & Public Participation for Data Collection

- Mobile phones are promising devices for data collection
- Possibility to transfer data by different means (Cellular networks, Internet, infrared, radio, television, fax)
- Possibility to transfer data in a variety of formats (text, photo, video, sound)
- Positive experiences of public participation in monitoring
- Public awareness on environmental issues
- Improvement of collaboration among all stakeholders
- Cost effectiveness of data collection activities
- High coverage in space and time.



CONCLUSION

- Monitoring provides the objective evidence necessary to make sound decisions on managing water quality today and in the future.
- Water-quality monitoring is used to alert us to current, ongoing, and emerging problems; to determine compliance with drinking water standards, and to protect other beneficial uses of water.
- Assessments based on monitoring data help law makers and water managers measure effectiveness of water policies, determine if water quality is getting better or worse, and formulate new policies to better protect human health and the environment.
- There is No holistic solution exists to cover all steps of water quality monitoring programs. Intelligent decision support systems (DSS) are needed in support of watershed managers.
- Participative geographical information systems (GIS) are useful to tap into local knowledge. Stakeholder involvement is necessary for successful integrated watershed management.

The ten basic rules for a successful assessment progamme

1. The objectives must be defined first and the programme adapted to them and not *vice versa* (as was often the case for multi-purpose monitoring in the past). Adequate financial support must then be obtained.
2. The type and nature of the water body must be fully understood (most frequently through preliminary surveys), particularly the spatial and temporal variability within the whole water body.
3. The appropriate media (water, particulate matter, biota) must be chosen.
4. The variables, type of samples, sampling frequency and station location must be chosen carefully with respect to the objectives.
5. The field, analytical equipment and laboratory facilities must be selected in relation to the objectives and not *vice versa*.
6. A complete, and operational, data treatment scheme must be established.
7. The monitoring of the quality of the aquatic environment must be coupled with the appropriate hydrological monitoring.
8. The analytical quality of data must be regularly checked through internal and external control.
9. The data should be given to decision makers, not merely as a list of variables and their concentrations, but interpreted and assessed by experts with relevant recommendations for management action.
10. 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.

Thanks for your attention