# Water Quality Monitoring Sampling and Instruments

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# Discussion

What are the steps needed to setup a hydrologic and water quality monitoring program in your country?

# Defining Monitoring

- Monitoring is defined by the International Organization for Standardization (ISO) as: "the programmed process of sampling, measurement and subsequent recording or signalling, or both, of various water characteristics, often with the aim of assessing conformity to specified objectives".
- This general definition can be differentiated into three types of monitoring activities that distinguish between long-term, short-term and continuous monitoring programmes as follows:
- ***Monitoring*** *is the long-term, standardised measurement and observation of the aquatic* environment in order to define status and trends.
- ***Surveys*** *are finite duration, intensive programmes to measure and observe the quality of* the aquatic environment for a specific purpose.
- ***Surveillance*** *is continuous, specific measurement and observation for the purpose of water* quality management and operational activities.

# Why Monitor Water Quality?

**5 Reasons:**

1. Characterize waters and identify changes or trends in water quality over time
2. Identify specific existing or emerging water quality problems
3. Gather information to design specific pollution prevention or remediation programs
4. Determine whether program goals -- such as compliance with pollution regulations or implementation of effective pollution control actions -- are being met
5. Respond to emergencies, such as spills and floods

# The Aquatic Environment

- The quality of the aquatic environment is a broader issue which can be described in terms of
  - water quality,
  - the composition and state of the biological life present in the water body,
  - the nature of the particulate matter present, and
  - the physical description of the water body (hydrology, dimensions, nature of lake bottom or river bed, etc.).

# Characteristics

- **Based on 3 criteria:** Physical, Chemical and Biological Characteristics

**Physical Characteristics**

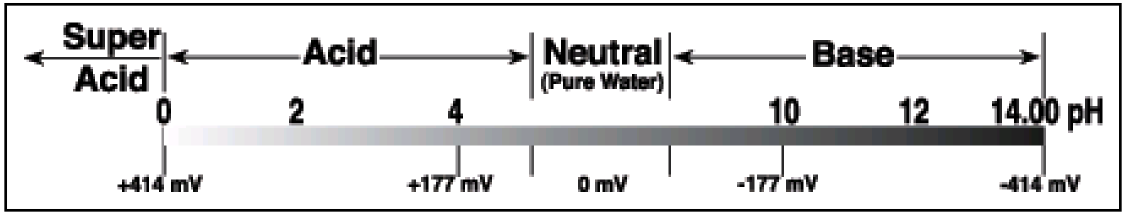
- Includes *turbidity*, *colour*, *taste*, *odour* and *temperature* measurements
  - **Turbidity**: The clearness of the water, as affected by suspended solids
    - Measured in nephelometric turbidity units (NTU). Nephelometric means that the measurement has been arrived at through the estimation of light absorption.
    - The more turbid a water, the less light there is available for photosynthesis
  - **Colour**: The presence of colour in water
    - Ideal colour is colourless for drinking water
    - Affected by suspended solids, usually organic constituents
  - **Taste**: The presence of a taste in water
    - Drinking water quality measurement
    - Is affected by the presence of dissolved inorganic substances (i.e. Mg, Ca, Na, Cu, Fe and Zn)
  - **Odour**: The presence of odour in water
    - Often Affected by the presence of organic constituents
  - **Temperature**: The temp. of surface waters at their respected depths
    - Effects the level of dissolved oxygen and metabolic rate of aquatic fauna
    - Most fish species require a temp. range of 5-20°C and a DO concentration of 5 g $m^{-3}$

# Characteristics

**Chemical Characteristics**

- Includes all organic and inorganic dissolved and particulate constituents. Dissolved constituents may exist as ions or dissolved gasses. The presence of these compounds in turn effects the *pH*, *salinity* and *hardness* of water.

  - **pH**: A measurement of the acidity or alkalinity of the water relative to the ionization of pure water
    - Measured on a scale of 0-14 with 7 being neutral (pure water)




    - The more H+ ions in the water the more acidic the solution is and therefore lower pH
    - Healthy pH range for surface waters = 6-8
    - pH is important because it effects the level of photosynthesis by aquatic flora. Lower pH allows more $CO_2$ to remain in solution (and not transformed to carbonate or bi-carbonate) and therefore accessible by the flora.

# Characteristics

## Chemical Characteristics (Con't)

- **Salinity**: The saltiness or dissolved salt content of a body of water
  - The concentration of ionic constituents ($CO_3^{2-}$, $SO_4^{2}$, $Cl^{-}$) dissolved in water
- **Hardness**: Water which has a high mineral content
  - Measured based on the presence of ions of the metals $Ca^{2+}$, $Mg^{2+}$ and $Fe^{2+}$ in the water
  - Drinking water quality measurement – causes scaling, soap scum.


# Characteristics

**Biological Characteristics**

- The abundance and distribution of aquatic life (microscopic viruses, bacteria and protozoans; as well as phytoplankton, zooplankton, insects, worms, large plants and fish can be used as indicators to determine the health of a water body.

**Key Indicators**

- **Blue-Green Algae (bacteria):** Microscopic in size, however, when a large outbreak is present, it may be seen as a blue-green haze. Toxins produced by the cyanobacteria have caused death of wild animals, farm livestock and domestic pets which have consumed the contaminated water. The toxins can produce a painful rash on human skin.
- **Fecal Coliforms**: Bacteria which live within the intestines of mammals. Presence of it in water indicates that sewage is present. Can be fatal if consumed by humans.

Source: Univ. of Toledo

# Monitoring Scenarios

- From fixed sites (long term data)
  - Fixed interval
  - Varied interval (flow or time dependent)
- From random sites
- From specific sites after an event (i.e. chemical spill, or implementation of a BMP or regulation

# Water quality: concentrations vs. loads

- Concentration: standards? thresholds?
- Loads: how much is lost in the end? TMDL?
- Generally both important and monitored
- Loads = concentration X flow

# What type of monitoring?

- At intervals (fixed or random)
- Continuous (small intervals)

# Concentration data

- Parameters often monitored:
  - pH
  - Conductivity
  - Dissolved oxygen
  - Nitrates
  - Phosphorus
  - Bacteria
  - ….

# Concentration data

- Traditionally, measurement of concentrations involves taking water samples
- Sampling:
  - – Composite
  - – Discrete
    - Grab
    - Fixed interval (time, volume)

# Concentration data – sampling procedure

- Bottle:
  - Material
  - Size

- Storage:
  - T°
  - Time
  - Light conditions

http://www.sara-tx.org/site/water_quality/laboratory_services.html

# Concentration data – analysis

- Laboratory vs. on site:
  - Parameter
  - Instrumentation
  - Number of samples

  … Time and cost

# Grab sampling

# Composite sampling


# Automated Sampling

**American Sigma 800**

- Used for sampling surface runoff

- Capable of taking discrete or composite samples, based on bottle configuration
- Is compatible with CS dataloggers, and therefore sampling patterns can be developed in the datalogger program
- Samplers have an optional feature of being refrigerated, for monitoring of temperature dependent parameters
- $$$

# Automated Sampling

**Global Water WS 300**

- Subsurface or surface drainage sample can be pumped automatically
- Mainly used for composite samples; dual bottle configuration possible
- Compatible with CS dataloggers, and therefore sampling patterns can be developed in the datalogger program
- $$

# Water Sampling Strategy

Discrete vs. Composite – Which to choose?

- More accurate analysis of event
- More work
- More expensive

- Less accurate analysis of event
- Less work → less $$ spent

# Water Sampling Strategy

## Geometric vs. Constant - Which to choose?

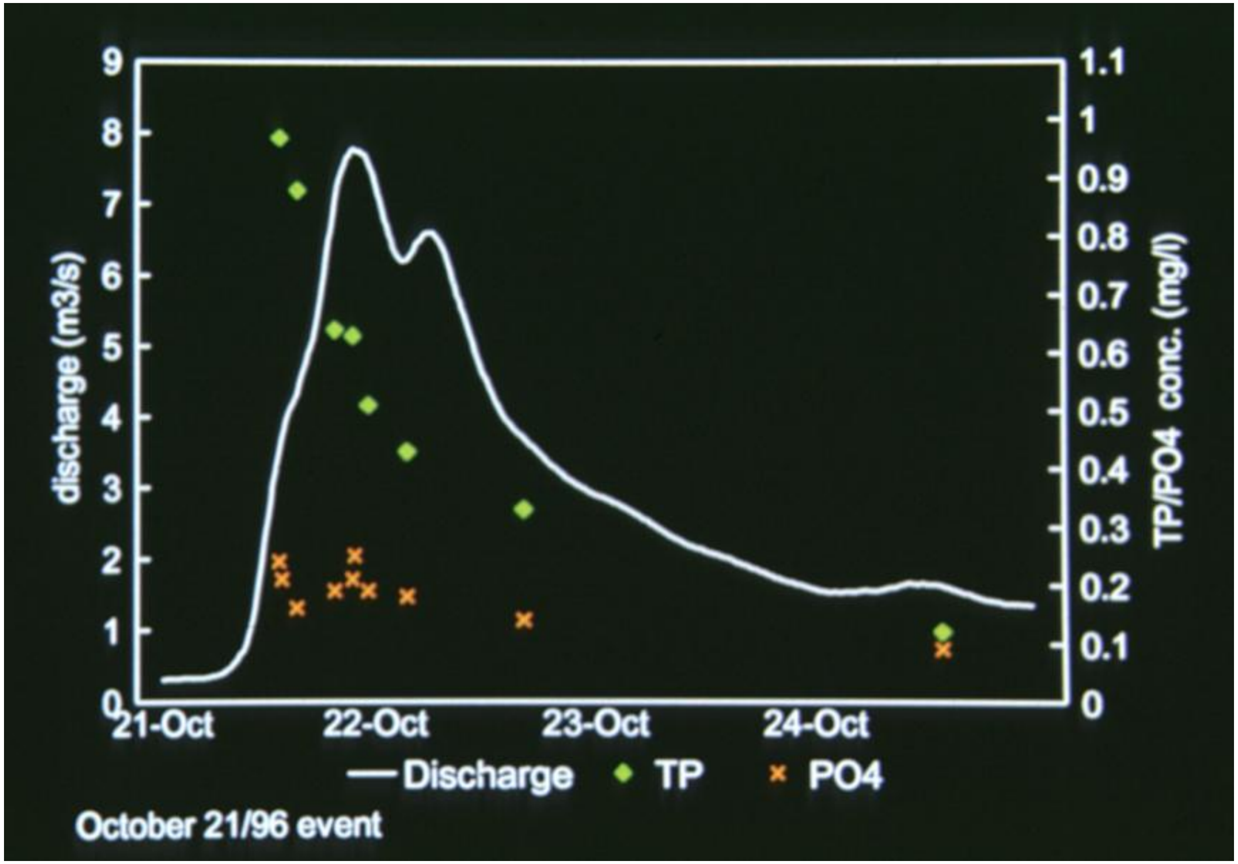
| Sample Number | Geometrical Increment | Volume (mm of runoff over surface area) | Cumulative Volume (mm of runoff over surface area) |
|---|---|---|---|
| 1 | $0.2 * 2^{(n-1)}$ * | .2 | .2 |
| 2 | | .4 | .6 |
| 3 | | .8 | 1.4 |
| 4 | | 1.6 | 3.0 |
| 5 | $2 * 1.25^{(n-5)}$ * | 2.0 | 5.0 |
| 6 | | 2.5 | 7.5 |
| 7 | | 3.13 | 10.63 |
| 8 | | 3.91 | 14.54 |

- Allows for comparison of results across all sizes of storms
- Can miss the falling limb of the hydrograph during small events

| Sample Number | Volume (mm of runoff over surface area) | Cunulative Volume (mm of runoff over surface area) |
|---|---|---|
| 1 | 0.2 | 0.2 |
| 2 | 0.2 | 0.4 |
| 3 | 0.2 | 0.6 |
| 4 | 0.2 | 0.8 |
| 5 | 0.2 | 1.0 |
| 6 | 0.2 | 1.2 |
| 7 | 0.2 | 1.4 |
| 8 | 0.2 | 1.6 |

- Constant discharge between samples
- Better for small events (more samples)

# Water movement and phosphorus movement during a rainfall event



# Discrete sampling


# Discrete sampling

# Instruments for on-site measurements

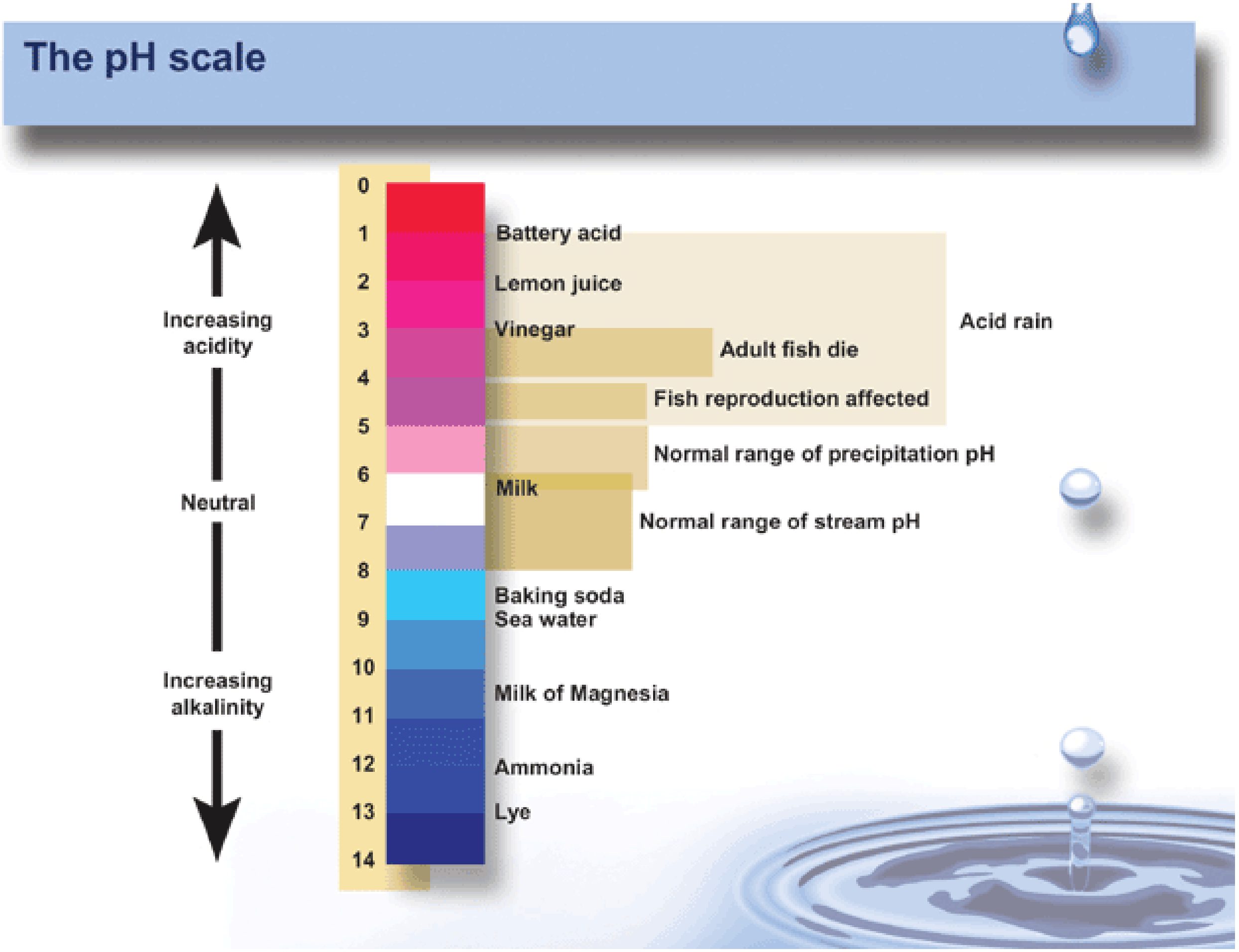

On occasions, an operator needs an indication of water quality "RIGHT NOW". For these situations, sending a sample to the lab, and getting results in a few days, is not an option. (our water treatment plant, or a waste water plant is an example of such a case).

There is a range of portable devices which give you a rapid indication of water quality. A pH meter is the simplest example. These units can be equipped with Ion Selective Electrodes (ISE) to evaluate other parameters. Another such instrument is the Dissolved Oxygen meter from YSI. YSI makes probes which can be hand held, or which can be installed in situ, and left for extended periods of time. Those devices have datalogging capabilities.

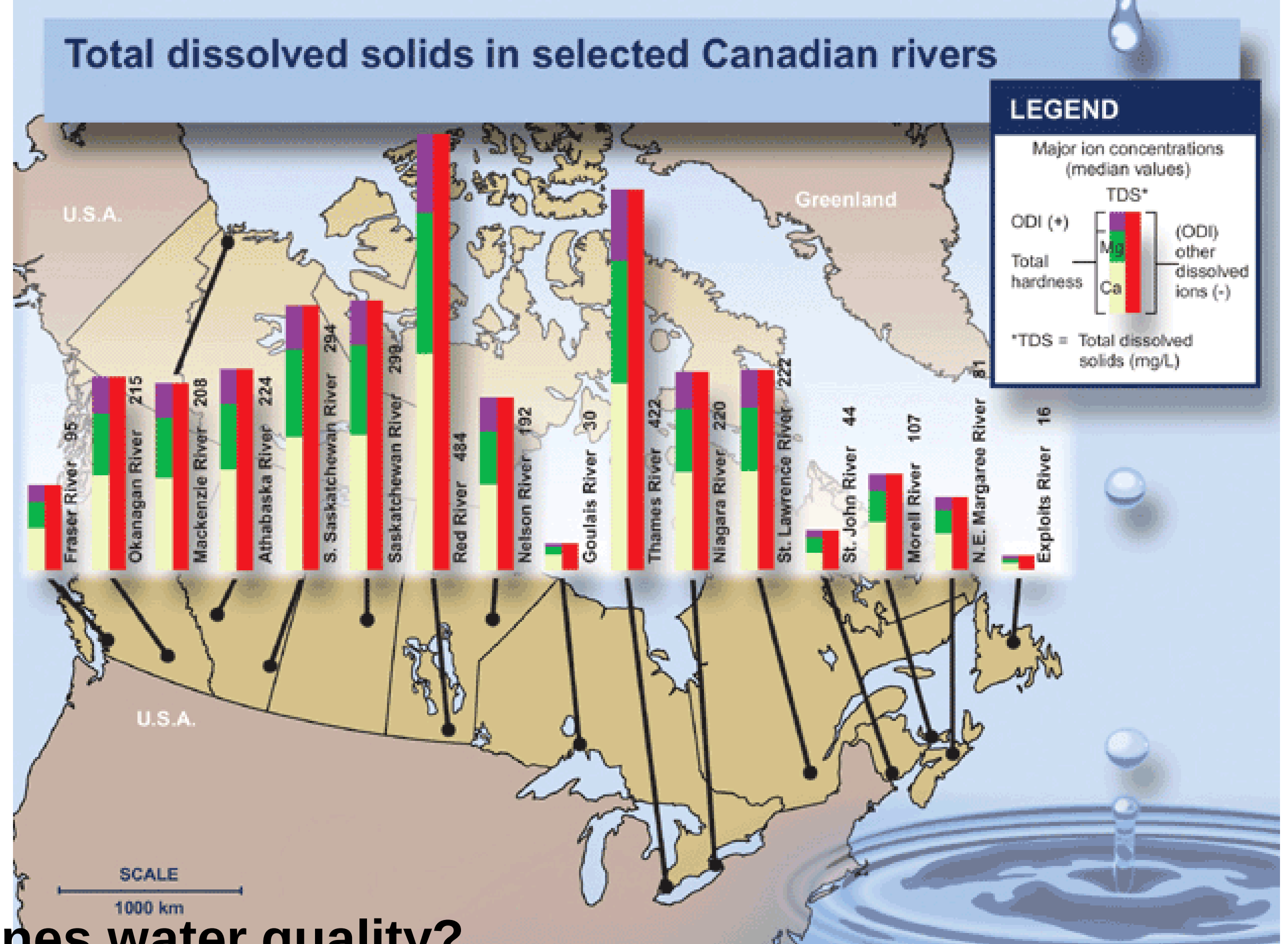
The HACH unit is a Spectrophotometer. You fill the two optically matched sample bottles, and add a chemical reagent to one of the samples. The greater the presence of a certain parameter, the stronger the colour developed. You then evaluate the light transmission through the sample, which is a function of the colour (which is a function of the concentration).

# Instruments for on-site measurements - YSI multiparameter probes

# The pH scale




http://www.ec.gc.ca/water/en/manage/qual/e_ph.htm




# What determines water quality?

The water of even the healthiest rivers and lakes is not absolutely pure. All water (even if it is distilled) contains many naturally occurring substances – mainly bicarbonates, sulphates, sodium, chlorides, calcium, magnesium, and potassium.

They reach the surface and groundwater from:

soil, geologic formations and terrain in the catchment area (river basin);

surrounding vegetation and wildlife;

precipitation and runoff from adjacent land;

biological, physical and chemical processes in the water;

human activities in the region.

http://www.ec.gc.ca/water/images/manage/qual/a3p2e.htm

# Monitoring and sampling of surface runoff

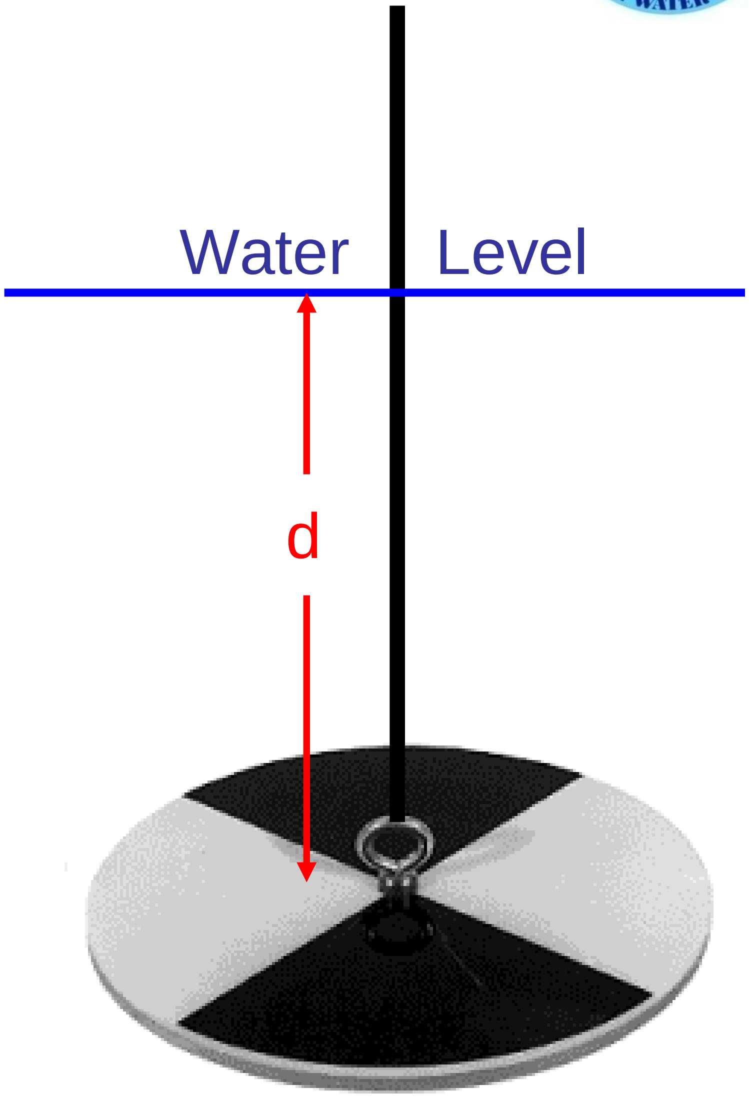
# Monitoring and sampling of surface runoff

# Monitoring and sampling of subsurface drainage

# Water Quality Instruments

**Turbidity**

- *a* secchi disk is a manual method used to measure turbidity
- scientist measures the depth at which the secchi disk is no longer visible
- relative scale
- procedure is not standardized
- cheap method



# Water Quality Instruments

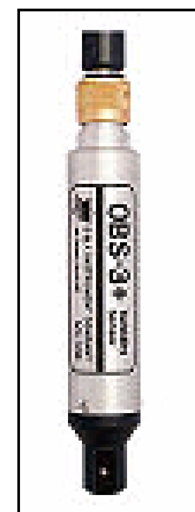
**Turbidity (Con't)**

- *Campbell Scientific Hydrolab Surveyor-4a*

    - Hand-held device
    - Multi-probe (pH, DO, salinty, EC, TDS, ORP)
    - 0-3000 NTU detection
    - GPS capability
    - $$

- *Campbell Scientific Turbidity Monitor – OBS-3PLUS*

    - Permanently fixed
    - 0-4000 NTU detected by  the backscatter method



# Water Quality Instruments

**Temperature**

- *Regular old Thermometer*

  - portable
  - variable depth
  - cheap

- *Quanta P Hydrolab*

  - portable device
  - Variable depth (100m max)
  - -5 to +50°C detection
  - multi-purpose (DO, EC, pH, salinity)
  - $$

# Water Quality Instruments

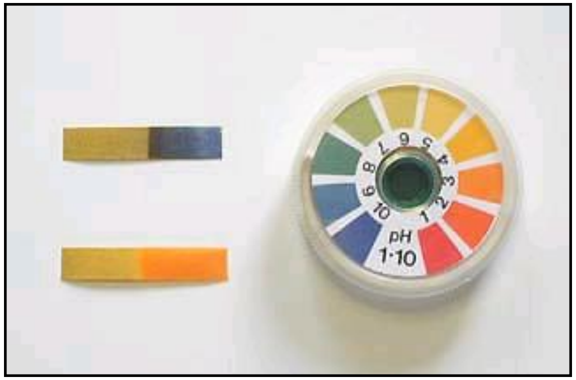
**<u>Temperature</u>**

- *Campbell Scientific 107B*
  - fixed device (submerged up to 50')
  - Thermistor technology
  - -40 to +50°C detection
  - $$

- *Campbell Scientific Infrared Radiometer*
  - fixed device
  - -15 to +60°C detection
  - $$

# Water Quality Instruments

## pH, EC, ORP Salinity




- *Litmus Paper*

  - portable
  - cheap
  - simple

- *EUTECH Cyberscan pH620*

  - portable
  - Multi-parameter (pH, [ion], EC, ORP)
  - $$

# Water Quality Instruments

**Metals, Nutrients, etc.**

**Most often, measurements are done in the lab**

- *Hach DR 5000 Spectrophotometer*

  - used for metals, nutrients, hydrocarbons
  - lab bench top
  -$$

**However, technology is available for in field measurements**

- *Hach HSA-1000 Analyzer*

  - used for Pb & Cu
  - portable
  - instant results
  - $$

# Water Quality Instruments

- *Hach DR/890 Portable Colorimeter*

  - 90+ parameters
  - portable
  - instant results
  - very $$$


- *Auto Analyzer*

# Water Quality Instruments

**Algae**

- *Campbell Scientific Hydrolab Surveyor-4a*

  - Hand-held device

  - instant results

  - measures Chlorophyll a using a submersible fluorescense sensor

  - Multi-probe (pH, DO, salinty, EC, TDS, ORP)

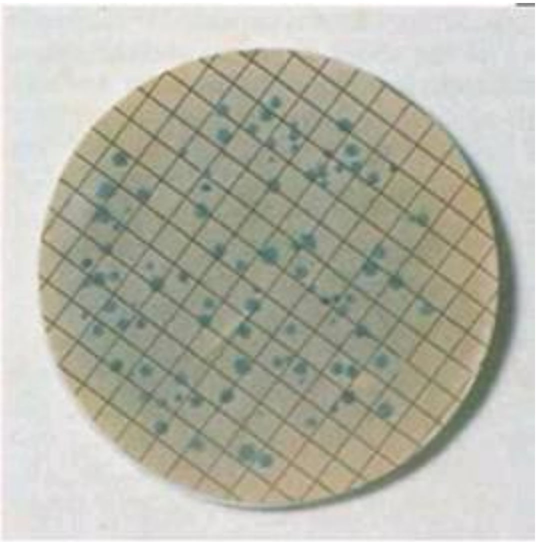
  -GPS capability

  - $$


# Water Quality Instruments

## Fecal Coliforms

****Most often, measurements are done in the lab by the *Membrane Filtration Procedure*****



Source: Free Your River

# Water Quality Instruments

## Fecal Coliforms

- *Research International Analyte 2000*

  -Fiber Optic Fluorometer

  -Portable device

  - near instant results (15 min)

  -$$

**Thanks to Peter Enright and Mark Eastman for pictures and slides in this presentation**

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