UNIVERSIDAD NACIONAL DE CAÑETE

UCAM & UNDC

Peru Project

Fieldwork & Laboratory Manual

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Contents:

Introduction:

Organising the field data collection

It is best to collect the data in a team of four people divided in to two pairs.

***The tasks -**

a.Water samples: sample according to site.

b.Sediment samples (suspended load, bed & bank): two samples per site.

c.Water tests: pH, conductivity, water temperature, total dissolved solids, dissolved oxygen & oxygen reduction potential.

d.River channel data: width, depth & velocity.

e.Atmospheric data: air temperature & air pressure.

***Division of tasks –**

-Tasks **a, c** and **e** could be undertaken by one team

-Tasks **b** and **d** could be carried out by the other team.

Section 1: Equipment calibration

Equipment calibration is the most important step to ensure the accurate measurement of parameters. Check each item of equipment for correct functioning and calibrate according to the following procedures **before** starting a field visit.

NB. ensure that all batteries are installed and charged, and that spares are available.

Safety: refer to the Risk assessments in the Appendices for safe handling of equipment.

1.1. Hanna Multiparameter (HI98194)

Measuring: pH, Electrical conductivity, Dissolved oxygen (DO), Total Dissolved Solids (TDS), Atmospheric pressure & Water temperature.

Equipment & Materials:
Hanna Multiparameter (HI98194) & Accessories; Allen key (to remove probes); pH probe spare; spare DO probe; space EC probe; spare DO membranes; Conductivity calibration solution (HI70031); Electrode fill solution (HI7042S); Quick calibration solution; Sodium sulphate; pH 4.01 buffers (HI70004P); pH 7.01 buffers (HI70007P); pH 10.01 buffers (HI70010P); Batteries (AAA); Distilled water; Electrode storage solution (HI70300);

Check and take action:
***Allen key:** available to remove/tighten probes.
***Battery life:** fit / replace batteries (AAA).
***Electrode connection:** fix connections.
***Cleaning & Calibration:** see below.

i.Unscrew the storage container and **dispose** of any storage solution within it.

NB. Take care to dispose of the storage solution in an appropriate way.

ii.Remove the caps on any of the probes and **rinse** the probes with distilled water.

Note: after prolonged non-use the pH/ORP probe will need changing.

Note: after prolonged non-use the DO membrane will need changing – follow instructions that come with the new 'DO membrane'.

iii.Use the brush provided to **remove** any deposits/sediments on the probe / sensors that have accumulated during storage.

Note: Salt deposits may accumulate on the pH/ORP sensors after long periods of storage. This should be removed completely using the brush with distilled water. It may be necessary to leave the probe sitting in a solution of sodium sulphate for an hour if the deposits remain.

iv.Turn on the multiparameter by pressing the red/white button.

v.Confirm that the multiparameter is reading all probes/sensors one-by-one by pressing the button with the white dot (top left).
Use the arrows to **scroll down** and check that the probe/sensor is registering each reading.

vi.Select '*Menu*' and scroll down to '***Calibration***'.

vii.<u>OPTION 1</u>: Select '*Quick calibration'*

Note: only select this option if the equipment has been used recently, or just checking. If it has not been used for many weeks or months, then a full calibration is required.

***Fill** a container(wide test tube: wide enough to accommodate all the probes) so that it is one third full with the '*Quick calibration solution'* and place the probes in the container.

***Wait** until it is **confirmed** on the screen that each probe/sensor is calibrated (ready).

***Remove** the probes/sensors from the container and hold them in the air until it is again **confirmed** on the screen that each probe/sensor is calibrated (ready).

NB. This is especially important for the calibration of the oxygen probe- hold the probe very close (almost touching) the water surface to calibrate for humid air.

***Select '*Tick*'** (top left – white dot button) when done. The multiparameter is ready for use.

***During more or less **daily use**, **fill** the storage container with tap water and refit to the device so that the probes are kept moist.
If it is **not** going to be used for **many weeks**, then follow the **Storage procedures** in **Section 5.**

viii.<u>OPTION 2</u>: Select *'Single param. Calibration'* (prior to start of field work)

***Select** the parameter of interest: pH, Conductivity, ORP, or %DO and follow the instructions using the correct buffer fluids.
NB. 'Factory reset' should be **selected** prior to selecting each parameter.

-pH: select "*Calibrate pH*" and then **'Factory reset' - calibrate** using up to 3 buffers (pH 4.01, 7.01, 10.01 or one custom buffer).

-ORP: separate calibration is **not** required for a new ORP sensor because it is on the pH probe and they calibrate together, but doing so does establish a baseline that can be used as a comparison for future validations. Calibration is used to compensate for changes due to contamination of the platinum surface and drift in the reference electrode.
NB. A relative mV calibration can also be made to remove the voltage attributable to the Ag/AgCl reference electrode (to display the ORP versus a SHE (standard hydrogen electrode)). This is really an arithmetic correction and is correct only at the standard temperature. For example, test solution HI7022 reads 470 mV at 25 °C versus the Ag/AgCl reference. The ORP mV versus a SHE would be 675 mV (add 205 mV to the observed value).

-%DO: although it may be easier to calibrate the DO sensor prior to deployment, it is advised to calibrate at the site of deployment. Errors in measurement may result if altitude and barometric pressure differ between the calibration and measurement site. Replacing the membrane cap and electrolyte solution is the best way to perform periodic maintenance as cleaning will probably damage the membrane.

-EC: the calibration is automatic.

***To replace** the **membrane cap** and **electrolyte solution** –

-remove the existing membrane cap;

-soak the probe in electrolyte solution for several minutes;

-clean the end of the probe as necessary to remove any build up;

-rinse the probe with electrolyte solution;

-fill (fully) the membrane cap with electrolyte solution;

-tap the membrane cap firmly several times to ensure that any air bubbles are released. This can be checked by ensuring that –

-no air bubbles are visible through the membrane;

-the membrane is not wrinkled;

-the metal end of the probe is visible through the membrane.

-fit the small membrane cap rubber ring;

-place the probe in to the membrane cap and **tighten** carefully (do not overtighten);

Finally, **immerse** all probes in the multiparameter probe protective container filled with a **sodium sulfite solution** (1gr : 100ml) to calibrate all probes. The solution should be stirred well and left to stand for 10 minutes.

The DO probe takes time to **stablise** but should do so at or close to '0%'. **Remove** the probes from the liquid and **shake** gently to remove excess fluid. **Hold** just above the solution and it should stabilise at approx. 70%. **Reimmerse** the probes in the solution to confirm the DO % as 0%.

Section 2: WATER & SEDIMENT SAMPLING

Safety: Always wear gloves and appropriate PPEs when taking samples. Refer to the labels on bottles/tubes for chemical preservatives in them and read the risk assessments.

Important: The aim of collecting water and sediment samples is to obtain samples that are true representations of the water or sediment at the point of collection. That means preserving the sample according to the guidelines given below and avoiding any possible contamination.

2.1. Water sampling

-Collect water samples at each site in pre-cleaned HDPE bottles (cleaned with 1% hydrochloric acid, if available and distilled water).

-Rinse bottles for reuse with hydrochloric acid (1%) solution, if available, and distilled water until pH7. **Use** pH papers to check that the bottles are pH neutral (pH 7.0) and that they would not make any samples acidic.

-Rinse the HDPE bottles with river water at the sample site prior to collecting the sample.

-Prepare subsamples as follows:

- For **heavy metal, anion & cation tests** and **general** tests, water samples need to be filtered. **Collect** water into HDPE bottles and then **filter** into the PP sample tubes or bottles provided by SGS. (See sections A – C for instructions on filtering).
- For **COD, biological, pesticide, total nitrogen** and **total phosphate** tests, water samples should **not** be filtered. **Collect** the samples directly into the PP sample tubes or bottles provided by SGS.
- **Collect** 500ml of **filtered** water - for **alkalinity** and **nitrate** tests in the lab.

Notes:

-**Nitric acid** needs to be used to stabilise the samples for **metal** tests. The acid should be purchased as **ultrapure** (<99.99% trace metal basis) or distilled in the lab (double distilled is better but single distilled will be OK). If concentrated nitric is used, the molarity is about 15M and only 2-4 drops are required per 60ml of sample. The sample should have a pH as close to **2** as possible. **Check** with pH paper.
For practical purposes and safety, add the nitric acid to the test tubes in the lab.
NB. This should be supplied with instructions for its use by SGS.

-If nitric acid is not available, the sample must be **filtered in situ** directly in to the test tubes. Samples should be transferred to the analytical lab within two weeks, where the metal and cation samples should then be acidified to ensure all adsorbed or precipitated materials return to solution.
NB. If **cation and anion** samples are to be analysed **together** then do **NOT** acidify the sample. This will nullify the anion analysis.

-Tubes/bottles for pesticide tests may contain *sodium thiosulphate* which can be an **irritant** (**See Appendix:** Risk assessment for sampling preservation).

-Always use the correct bottle/tube for samples as they are specific for the component being tested. Plastic tubes cannot be replaced with glass ones and vice versa. Chemical preservatives should not be allowed to cross-contaminate the samples.

-Do not use bottles/tubes that are not supplied for this field visit. They may contain expired chemicals or not have been cleaned for the purpose, causing contamination of the samples.

-Do not rinse previously unused sample test tubes/small bottles with distilled water prior to introducing the sample.

Preparing filtered samples:

Filtration is used to remove turbidity due to any organic and inorganic particles/ sediments and biological materials to preserve the sample from degradation. Collect and preserve the filtrate on a filter paper.

A. Using a filter holder

Equipment & Materials: Swinex filter holder; gaskets; 0.20µm filter membranes; distilled water; tweezers; petri dishes;

Equipment set-up:

-Separate the two sections of the filter holder and **rinse** inside and out with distilled water.

-Separate a white filter paper from the blue protective disks/covers, without damaging the filter, and **place** inside the filter unit using tweezers.

-if there is wording or a grid printed on the filter, it should be facing upwards.

-Place the rubber '**O**' gasket on top of the filter paper and **screw** the two sections together.

-Attach the filter holder to the tubing for pump or to the syringe following Sections B and C.

Figure: (left) Swinex filter holder with two sections screwed. The inlet tubing/syringe is connected to the bottom (as shown in the photo above); **(middle)** Swinex filter holder with the filter holding section opened; **(right)** Tweezers are used to place and remove the filter in the filter holder.

(Please note that the last photo shows a laboratory filter holder, which is different to a Swinex filter holder)

After filtering samples from one site:

-Weigh the **empty bottle** before pumping the water into it. **Weigh again** with the filtered water in it. **Record** on field data sheet.

-Open the filter unit carefully and **remove** the filter paper using tweezers.

-**Place** the filter paper in a petri dish (keep **all** filter papers used at each site, if more than one used).

-Clearly **write** on the petri dish the site no., name, date and the amount of water that has passed through the filter (eg.213ml) and record on the data sheet.

-Use distilled water to **clean** the filter unit before and after each site.

-Leave the filter paper to **dry naturally overnight** (lid partially covering) and **seal** the petri dish with parafilm **the next day.**

B. Using a peristaltic pump

Equipment & Materials: Geotech peristaltic pump; AC/DC combination power cable; rechargeable battery; DC power cable with car battery connectors; silicone tubing; distilled water; 500ml HDPE bottle; Swinex filter holder with a new filter paper inserted (See section A above); tubes/bottles for collecting filtered samples; HDPE bottles (1+ bottle).

***Equipment set-up:**

***Check** the pump 'on/off' button is in the 'off' position. **Connect** the power cables to the 12VDC supply at the back of the pump;

***Lift** the lever in the pump head and **move** to the left to open the pump head;

***Place** the tubing through the pump head;

***Move** the lever to the right to lock and **close** the pump head with the tube within it;

***Attach** the Swinex filter holder, containing a **new filter paper for each site**, to the tubing (if the filter clogs, more than one filter paper may be needed for one site. This can be minimized by making sure that there are no floating, large particles in the collected sample).

***Filtering the sample:**

-Collect a water sample in an HDPE bottle in the field.

-Weigh the empty sample collection bottle in to which the sample (ie.Metals) will be filtered.

-Place the left end of the silicone tubing in the HDPE bottle.

-Place the right end of the silicone tubing in to the sample collection bottle.

-Set the pump direction to 'forward' using the 'reverse/forward' button.

-Turn on the pump and **set** the speed to 3-4 (marked on the dial).

-Once the sample collection bottle is filled, **reweigh** the sample collection bottle and **calculate** the new weight / approximate volume of water in the sample collection bottle.

-Label the sample collection bottle with the site no., name, date and **amount of water in the bottle**. **Tighten** the cap well and **secure** with parafilm.

-**Repeat** the above steps for the next sample (ie.COD).

-If there is a lot of sediment, the filter paper may become **clogged** in which case **remove** the filter paper following the procedure below and **use** a new filter paper.
NB. All filter papers used at a site need to be retained.

-After collecting all filtered water samples for the site, **turn off** the pump.

<u>After filtering samples</u>:

***Keep the filter paper -**
-Remove the bottom half of the Swinex filter while making sure not to twist the silicone tubing.

-Remove the filter paper with tweezers and **place** in a petri dish labelled with site no., name, date and the **total weighed amount** of water that has passed through the filter (eg.213ml).

-Leave the filter paper to **dry naturally overnight** (lid partially covering) and **seal** the petri dish with parafilm **the next day.**

-NB. If more than one filter paper used due to the large amount of sediment present, follow this procedure for all filter papers used.

***Cleaning the silicone tubing -**
-Place one end of the tubing in to a bottle of distilled water.

-Turn on the pump while keeping a waste container at the right end of the tubing to collect water that is cleaning the tubing and the top part of the Swinex holder. Now the tubing is clean and ready for use at the next site;

-Tubing can be reused at the sites as long as this procedure is followed and it shows no mechanical damage;
Note: keep the tubing clean and dust free during transport between the sites.

C. Using syringes:

Equipment & Materials: 50ml syringe (1 per site); Swinex filter holder with a new membrane inserted (See Section A above); tubes/bottles for collecting filtered samples; HDPE bottles (1+);

-Fill a new syringe with the required amount of water from a HDPE bottle;

-Attach the syringe to the top inlet of the Swinex filter;

-Place a clean PP tube of HDPE bottle for collecting the filtered sample and compress the syringe until the required amount of water has been filtered;

-Once the water sample has been added to the Sample collection tube, the cap must be fully tightened and then secured with parafilm;

Note: Use a new syringe for each site since proper cleaning of the syringe may be difficult.

Water samples collection for testing for 'heavy metals'

For the water samples destined to be tested for 'heavy metals', the water sample must be stored in plastic test tubes that contain 0.5ml or 3 drops of nitric acid (70%, 99.99% trace metal basis) as appropriate to bring the solution to **pH of 2**.

Note: Past experience indicates that changes in atmospheric pressure at altitude can cause **nitric acid** to **escape** from the test tubes, if the test tubes have been pre-filled.

In this case, the following procedure should be followed –

-a tightly closed bottle of nitric acid should be carried, regularly monitored and **carefully stored** during field visits.

-one person should be designated and responsible for handling the nitric acid bottle at all times.

-Nitric acid should only be added to test tubes under controlled conditions, in line with the all-risk assessment procedures, with a pipette (see section 'Use of pipette').

-Nitric acid should either be added first to the test tubes and the water sample added subsequently with a pipette at the site. Or, add nitric acid is added to the sample in the lab.

-once the water sample and nitric acid have both been added to the test tube, the cap should be tightly fitted and then secured with *parafilm.*

2.2. Sediment sampling

A. Sediment sample collection

Equipment and materials: plastic sample containers or plastic bags (small – 2-3 per site); spoon/spatula/trowel; marker pen; gloves;

Sample collection:

-Collect sediment samples at all sites if possible, from the river **bed** (permanently under water) and **banks** (rarely under water);

-The sample should consist of **finer** material: silt/sand. If possible, take the sample from just below the surface of the river bed or bank. Fill the bag/container to a depth of about 3cms;

-**River bed: scoop** a sample from as far out in to the channel as is practical (safe);

-**River bank: scoop** a sample from a place **higher** up the bank or lakeside that is clearly affected occasionally by the river when it is in flood;

-Leave the container/bag to 'rest' and then **drain** out as much water as possible prior to sealing;

-Later the bag can be **weighed** to produce a sample of **100grs plus** and sub-samples taken.

-**Seal** the container/bag with *parafilm* and clearly **label** the container with the site no., site name, date and time of collection.

B. Sediment size recording

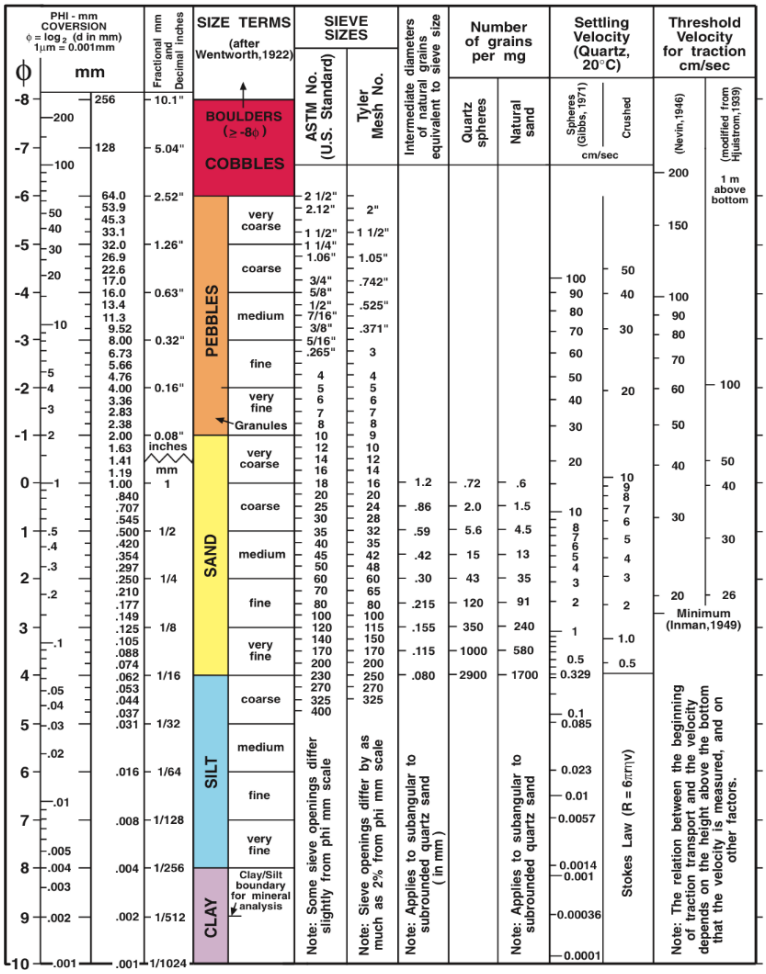
The size of the sediment occupying the river channel needs to be recorded.

Sediment size data is recorded by observation with reference to the **Wentworth sediment scale** chart – please see below.

An estimation should be made of the approximate percentage of the main sediment types (qualitative not quantitative) occupying the river channel. The terminology as stated in the Wentworth sediment scale chart should be employed.

This data can be double checked subsequently by referring to photos taken of the channel.

Material	Size
Sand	<2mm
Gravel	2mm – 15mm
Pebbles	15 – 60mm
Cobbles	60 – 250mm
Boulders	250mm+



Section 3: FIELD MEASUREMENTS

3. 1. Physico-chemical measurements

Parameter such as pH, Electrical conductivity, Temperature, Dissolved oxygen and ORP in water samples depend on many environmental factors including air pressure, temperature and bacterial activity. These parameters are therefore highly susceptible to rapid change after collection. Measurements should be taken on-site to ensure accurate values for these parameters – they are displayed across three screens on the multi-parameter.

All meters should be calibrated according to **Section 1** before measurements are taken.

1. Hanna Multiparameter (HI98194)

Measuring: pH, Electrical conductivity (EC), Total dissolved solids (TDS), Dissolved oxygen (DO) & Water temperature.

Equipment & Materials: Hanna Multiparameter (HI98194) (calibrated); distilled water; tissues;

Equipment set-up:

-Clean the electrodes with distilled water, ensuring that the water enters the gap at the end of the sensor, to remove any salts from the saline solution it is stored in.

-The probes (electrodes) can be directly immersed in the river/lake for measurements.

A. pH measurement:

***Measurement unit:** pH

-Place the end of the sensor in the water, ensuring that it is completely immersed in the water.

-Select the '**pH**' mode.

-Wait until the 'unstable' display disappears and then **read off** the result.

B. Electrical conductivity (EC) measurement:

***Measurement unit:** Low range (µS/cm), High range (mS/cm)

-While the end of the sensor is in the water [See above], **select** the '**conductivity**' mode.

-Wait until the 'unstable' display disappears and then **read off** the result.

C. Total dissolved solids (TDS) measurement:

***Measurement unit:** High (ppt) / Low (ppm)

-Keeping the sensor in the water [See above], **select** the '**TDS**' mode.

-Wait until the 'unstable' display disappears and then **read off** the result.

D. <u>Dissolved Oxygen measurment:</u>

***Measurement unit:** % and mg/l of DO.

-Keeping the sensor in the water [See above], **select** the '**DO**' mode.

-Wait until the 'unstable' display disappears and then **read off** the result.

E. <u>ORP measurements:</u>

***Measurement unit:** mV

-Keeping the sensor in the water [See above], **select** the '**ORP**' mode.

-Wait until the 'unstable' display disappears – this may take about 5 minutes - and then **read off** the result.

F. <u>Water temperature measurement:</u>

***Measurement unit: ˚C (degrees centigrade)**

-Keeping the sensor in the water [See above], **select** the '**Water temperature**' mode.

-Wait until the 'unstable' display disappears and then **read off** the result.

G. <u>Atmospheric pressure (Atm Pressure) measurement</u>:

***Measurement unit: mbar**

-The atmospheric pressure is displayed when the meter is turned on. **Read off** the value.

<u>After measurements:</u>

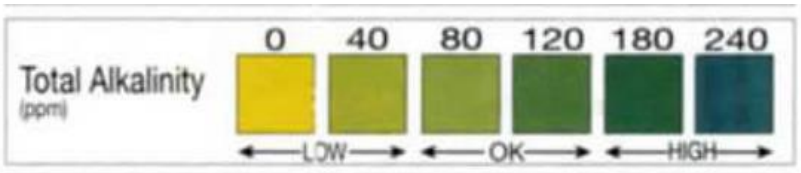
-**Clean** probes with distilled water after use.

-**Replace** the plastic cap on the pH sensor immediately to protect it.

-Storage: when the use of the multiparameter is complete, **place** a little storage solution (1cm) in the storage container to keep all the sensors moist and screw the storage container on to the multiparameter.

2. <u>Measuring Alkalinity</u>

A. <u>Alkalinity Test strips</u>



Equipment: Test strips (ie.Lamotte)

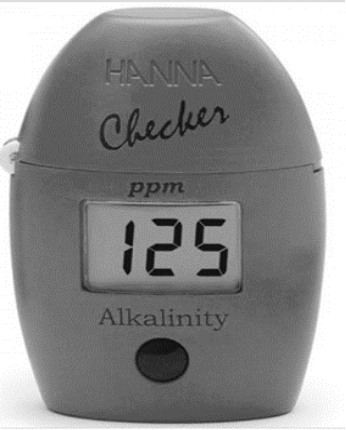
-use like pH strips and dip in to the sample. The test strips are designed to be read off immediately they have been dipped in the sample.

-record which of the options (ie. 0, 40, 80, 120, 180, 240 mg/L (ppm)) is indicated on the scale.

-if the colour is trending towards the next point on the scale, this suggests that the true result might be between the two points on the scale, **record** the lower reading with a '**+**' sign.

B. <u>Alkalinity tester</u>

Equipment: Hanna (HI-775 Freshwater Alkalinity Colorimeter - Checker®HC), Reagent kit, Batteries (AAA x 2)



-'***Zero***' the Checker®HC by **placing** the empty vial inside the checker and **pressing** the button.

-Remove the vial, **add** the water sample up to the line on the vial and **press** the button.

-when prompted to do so, **remove** the vial and **add** 10ml of the **reagent** using the pipette provided.

-place the vial back into the Checker®HC, **press** the button and read off the result.

-after each use, **clean** the vial thoroughly with distilled water.

NB.Check after each visit that there is sufficient reagent.

3.2. <u>River discharge rate measurements</u>

<u>Safety</u>: Avoid stepping into the river whenever possible. Measurements should be taken while in the river water only if the river is shallow, the bed is sturdy and the flow rate is slow.

<u>Theory</u>: The water discharge rate is calculated using the velocity (v1-v5) and depth (d1 - d5) measured at equal intervals along a selected cross-section (See figure below) of the river.

For this, first select a suitable cross-section of the river. Take a width measurement, calculate the intervals for depth and velocity measurements, and measure the velocity and depth at these intervals (See figure below).

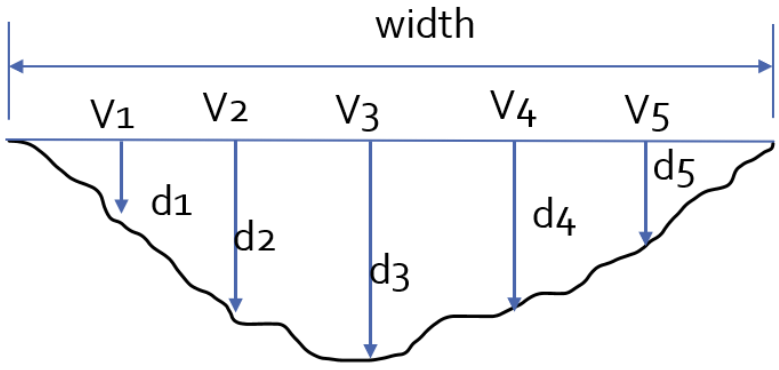


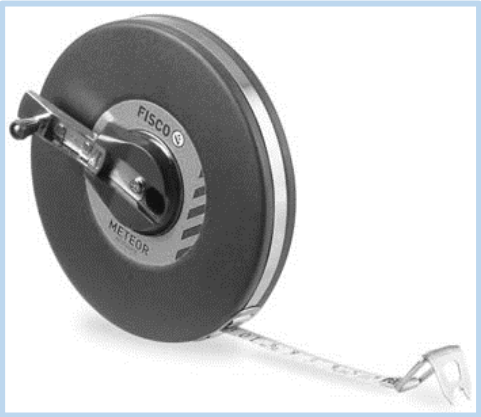
Figure: A cross-section of river showing the points where the measurements need to be taken

1.<u>Width measurement</u>

These measurements can be made using a tape measure or a telescope laser distance meter.

***Measurement: m (metres)**

A. <u>Using a tape measure:</u>



-Place the tape measure at a **90˚ angle** to the river bank.

-Measure from the point on one side of the river where the **water touches the bank** to where it touches the bank on the other side, **across the surface** of the river.

-If the bank is **muddy**, a decision will need to be made as to where the surface of the water is touching the firm bank. Too shallow water that is not flowing can be neglected from the width measurement. Note this in the data recording sheet.

- If the bank has an **overhang**, the tape measure must be placed under the overhang to where the surface of the water is touching the firm bank.

-Ensure that the tape is pulled tight **just above the surface** and is not dragged under water.

- If the width of the river is composed of **more than one channel** (braided), then the width of all channels needs to be measured to obtain the total width. In that case, measure the flow rate and depth of each channel as well to calculate the total discharge of the river at the site.

B. <u>Using Laser Works LW600SPI</u> (600m 6x) monocular telescope laser measurer:

This method is useful when it is difficult to reach the opposite bank of the river.

<u>Theory</u>:

- The meter measures both height and distance if the laser is projected at an angle. For river measurements, **keep the laser angle to zero.**

Method:

- Turn on the measurer.

- Stand on the edge of the river bank, in-line with where the **water touches the bank**.

- Aim the measurer **at** a **90˚ angle to the bank** (the display should show **0˚** laser angle with the ground) at the opposite bank where the water touches the bank.

Note: You should crouch down to obtain a proper alignment just above the surface of the river.

- Hold the measurer **very steady** and press the '**mode**' button.

- Look through the eyepiece until the letter '**Y**' appears on the screen.

- Press the '**on/off**' button once and the **width**, in metres, is displayed on the screen.

- **Repeat** 2-3 times to confirm the result.

*See also the guidance in **Section A** above.

C. Using a OTT MF Pro Flowmeter

(See Section 4 'Discharge' below)

2. Depth measurements

***Measurement: m (metres)**

A. Using a metre ruler

One depth measurement will not give a true measure of the depth across the river channel. Consequently, it is best to take 5 measurements at equal intervals along the selected cross-section to calculate the discharge rate as described in section 3.2. above.

-Divide the width measurement by **six** to obtain **five** locations at which to take **five depth measurements** at equal intervals across the river (Example: width = 6.0 m; 6.0/6 = every 1.0 m).

-Use a **metre rule** to measure the depth of the water. Extension pole or the flow meter pole may also be useful.

-Do **not** push the metre rule into the river load / bed material.

-Hold the metre rule **vertically** and read off the depth.

B. Using a OTT MF Pro Flowmeter

(See Section 4 'Discharge' below)

3. Velocity measurements

***Measurement: m/s (metres per second)**

A. Flowmeter method: only suited to small channels.

-The recordings should be taken at the same locations as the depth readings across the river.

-Place the flowmeter at **40% of the depth** into the river from the surface (60% of the depth up from the river bed).

-Make sure that there is no disturbance upstream (ie. someone in the river) and that the flowmeter **faces upstream**.

-The flowmeter must be held **vertically**, facing directly in to the current.

- Hold the flowmeter in position for **at least one minute** to note the average flow because at many sites the flow will vary over very short periods of time. Record the most stable velocity.

B. OTT MF Pro Flowmeter method: (See Section 4 'Discharge' below)

4. Discharge measurements

a. Introduction

Calculating river discharge accurately in river/water studies is important. In water quality studies, discharge can be used to give accurate measurements of the absolute quantities of a given trace metal at a particular point at a given time in a river.

When using the OTT MF pro flowmeter important questions to consider include **which section** of a river to use and **when** to take measurements.

****Remember no river profile is uniform across its width and measurements always need to be taken from bank to bank.**

*It is best to use straight sections, away from riffles or pools. Try to ensure the riverbed is not very uneven with large boulders or in turbulent sections or section with eddies (to avoid backflow).

*If a discharge measurement is needed to correspond with water quality sampling, timing is not a consideration. If you want a baseflow measurement, it is best to take the measurements at least five days after rains cease. If storm discharge profiles are required, measure when the rains cease and thereafter, at five hourly intervals.

Fig 1. Typical river section (Eustace Barnes)

b. Methods & Procedures

***Field protocol:** always take river measurements with at least one other person present. If anyone asks what you are doing explain.

***Equipment needed:** flowmeter & case, wading rods, screwdriver, tape measure, pegs, notebook, pens, camera and SD card.

***Clothing:** waders and rubber boots, depending on the river characteristics. A life jacket may be advisable, if a larger river is being measured.

NB. Ensure all electrical equipment is fully charged the day before.

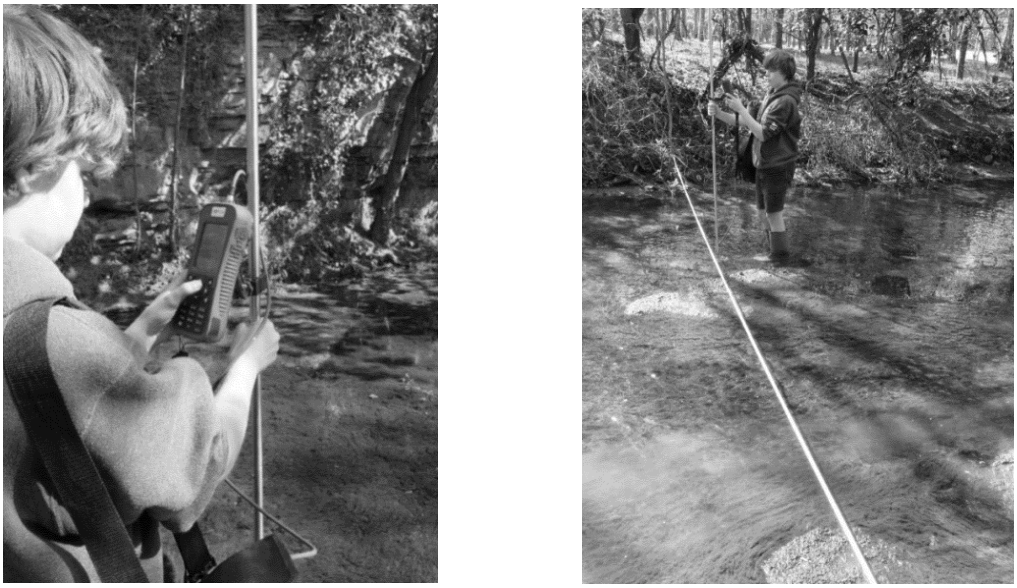


Fig 2. Setting up flow meter and tag line with measuring tape (right) (Eustace Barnes)

c. In the field: at the river bank

i.Assembling the OTT MF pro flowmeter -

*Attach the portable meter mount to the portable meter.

*Attach the portable meter and mount to the rod using the clamp on the mount.

*Attach the sensor lead to the portable meter.

*Attach the flowmeter sensor to the wading road– loosen the sensor head, slide the sensor down the rod, tighten the screw head to fix and align the sensor. Add rods as appropriate for the depth of the river.

Set the tape measure across the river with pegs. Ensure the tape measure is perpendicular to the river flow, is stretched tight and does not drag in the water. Fix with pegs to the bank.

NB. It does not matter if the river bank is aligned with 0.0m on the tape measure, the flow meter adjusts for this.

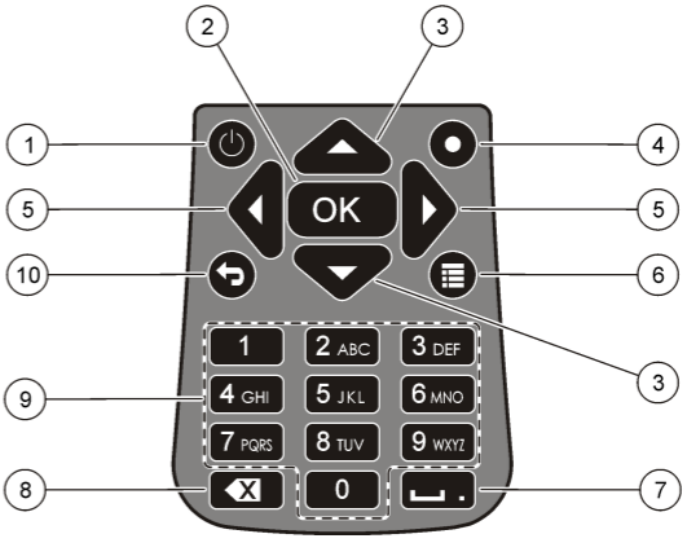
ii.In the field: ready to start -

You will be collecting data at regular intervals across the river. Those intervals are called stations. As a rule of thumb, stations should be about 0.5m apart. If there is a section where the river is deeper or the flow rate is higher, the intervals should be reduced. (See the recommended station intervals in figure 3 below).

Feet	Meters	Number of stations
< 1.6	< 0.5	5 to 6
> 1.6 and < 3.3	> 0.5 and < 1	6 to 7
> 3.3 and < 9.8	> 1 and < 3	7 to 12
> 9.8 and < 16.4	> 3 and < 5	13 to 16
> 16.4	≥ 5	≥ 22

Fig 3. Best practice ideal 'station interval' across varying river widths (OTT MF pro instruction manual)

To start, face **UPRIVER**, just below the tape measure, so that the distances can be easily read. Place the sensor in front of your feet so that readings are not affected by them. The river banks are to your left (LEW) and right (REW).



1 Power On/Off	**6** Main Menu
2 OK	**7** Underscore or decimal
3 Up and Down arrows	**8** Backspace
4 Quick Jump	**9** Alpha-numeric
5 Right and Left arrows	**10** Previous menu

Fig 4. OTT MF pro Flow meter keypad and controls. (OTT user manual)

iii.Setting the river information -

1.Turn on the flow meter. If a message appears that the sensor is not connected, either wait a short while or reattach the sensor lead to the meter.

2. Once connected, **click** the **OK** prompt using the OK button.

3. Scroll down to **'profiler'**. Click **OK**.

4. Enter operator name using the main menu keypad and click **OK**.

5.In the '**profiler**' menu **select** '**river**'. Click **OK**.

6. Enter the river name or site code. Click **OK**.

7.Ignore staff gauge reference. Click **OK**.

d. Starting data collection -

While standing in the river, facing upriver with the sensor and tape measure in front of you, **hold** the wading rod/flow meter **vertically** in the river with the **sensor pointing upriver** (the sensor is the black plastic covered oval knob).

8. From station information menu, **select**' **edge/obstruction'**. Click **OK**.

9. From '**select edge type**' select either left (LEW) or right (REW) depending on which side of the channel you are starting from. Click **OK**.

***At the <u>first</u> station: most likely the river bank -**

10.Return to the 'station information' menu. Select '**Distance to vertical**'. Click **OK**.

11. Enter the 'distance to vertical' from the tape measure. This is the measurement on the tape measure on the river bank at the water's edge (**NB.** it need not be zero). Click **OK**.

12.Return to the 'station information' menu. **Select** '**set depth'**. Click **OK**.

13.Enterthe maximum depth figure shown (**NB.** it is '**zero**' at the first station). Click **OK**.

***The first station data is now complete: there being no channel flow.**

14. Move to the second station in the river. **Scroll down** to **NEXT** and click **OK**.

15.Enter the next station reference number - the screen shows the previous station number. Click **OK**.

16. On the 'station information' menu, **scroll down** to '**Distance to vertical'**. Click **OK**.

17. Enter the distance given on the tape measure - the distance from the river bank. Click **OK**.

18. On the 'station information' menu, **scroll down** to '**set depth'**. Click **OK**.

19. On the 'station information' menu, **scroll down** to '**measure velocity'**. Click **OK**.

20. Select '**one point'** if the river is less than 50cm wide. **Select 'two point'** if the river is greater than 50cm wide. Click **OK**.

21. If '**one point**' selected, a box with '0.6' appears. Click **OK**.

22. On the next screen, a level (line) appears on a graph. **Adjust** the height of the sensor by **lifting** the rod up and down until a **green square** is **aligned** with the level (line).If it is not aligned, it will appear yellow or red. Click '**capture'**.
Hold the rod/sensor very steady, the meter will then record for 10 seconds and bleep. Click **OK.**

23.Click on '**verify'** to check the reading. Once confirmed, **select**' main' and click **OK.**

24.Move to station 3. **Repeat** 14-23 above. Working across the river, repeat for each station until you reach the opposite bank.

***To Finish -**
25. Once on the opposite bank, **scroll down** to '**edge/obstruction'**. Click **OK**.

26.Select '**edge type menu'**, scroll down to left (LEW) or right (REW) of the channel. (The opposite of what you selected for station 1). Click **OK**.

27. From the 'station information' menu, **select**' channel summary'. Click **OK**.
Using the '**cont**' button and clicking **OK** you can view, **area profile**, then **velocity profile** and then **discharge profile**. Those stations with greater than 10% channel flow are shown in red. You can adjust for this – see below. Click **OK**.

28. From the 'station information' menu, **select** '**save data'** and **exit**. Click **OK**.

29. Entera file name (site code plus date). Click **OK**.

30. From the **profiler** menu **scroll down** to 'files'. Click **OK**.

31. Scroll down through the files to find your file. Click **OK**.

32. Check data, then **Record** data. Click **OK.**

33. You automatically return to the list of files. Click **'done'**

NB.where stations record greater than 10% of the total discharge, you need to insert new stations.

e.Inserting or deleting a station -

Prev, Next, Ins and **Del** options show at the bottom of the display on the 'station' screen. **Prev** and **Next** are used to navigate to a previous or subsequent station. **Ins** and **Del** are used to insert or delete a station.

***Inserting -**

For example, after measurements have been taken at 10 stations, a user may wish to insert a new station between stations 3 and 4. The steps below describe how to do this.

1. Select **Prev** and push **OK** until the display shows the information for Station 3.

2. Select **Ins** and click **OK**. The instrument adds a new station named Station 4. Subsequent stations are automatically given new sequential numbers.

***Deleting -**

3. To delete the current station (when in non-fixed mode), select **Del** and push **OK.**

f.Making an estimate of the river discharge -

Once you have gone through the above process using the OTT MF pro flow meter, it is a good idea to see if the reading is about right. There are some easy field tricks that can be used to ensure your measurements are about right. However, this is no substitute for taking actual measurements.

NB. 1 cubic meter = 1,000 litres 0.5 cubic metres = 500 litres

So, what may appear a low reading, still represents a high channel flow.

***Worked examples -**

For channels with the following widths: 2m, 5m, 10m, 15m and 30m.

- *with average depths of 0.2 and 0.8m*
- *with average velocities of 0.2, 0.25, 0.8 and 1.2m/s*

***csa** = cross sectional area; **ms** = metre squared; **mc** = metres cubed; **D** = discharge.*

Channels 2m wide

1	(2m width, 0.2 depth, 0.25 velocity).	0.4 ms csa.	D = 0.1mc/s (100litres per second.)
2	(2m width, 0.8depth, 0.8 velocity).	1.6 ms csa.	D = 1.28mc/s. (1280 litres per second)

Channels 5m wide

3	(5m width, 0.2 depth, 0.25 velocity).	1.0 ms csa.	D = 0.25mc/s
4	(5m width, 0.8 depth, 0.8 velocity).	4.0 ms csa.	D = 3.2mc/s

5. (5m width, 0.8depth, 0.2 velocity).	4.0 ms csa.	D = 0.8mc/s
6. (5m width, 0.8depth, 1.2 velocity).	4.0 ms csa.	D = 4.8mc/s
Channels 10m wide		
7.(10m width, 0.2 depth, 0.25 velocity).	2.0 ms csa.	D = 0.5mc/s
8. (10m width, 0.8depth, 0.8 velocity).	8.0 ms csa.	D = 6.4mc/s
9. (10m width, 0.8depth, 0.2 velocity).	8.0 ms csa.	D = 1.6mc/s
Channels 15m wide.		
10.(15m width, 0.2 depth, 0.25 velocity).	3.0 ms csa.	D = 0.75mc/s
11.(15m width, 0.8depth, 0.8 velocity).	12.0 ms csa.	D = 9.6mc/s
12.(15m width, 0.8depth, 0.2 velocity).	12.0 ms csa	D = 2.4mc/s.
Channels 30m wide.		
11. (30 m width, 0.2 depth, 0.25 velocity).	3.0 ms csa.	D = 1.5mc/s
12. (30 m width, 0.8depth, 0.8 velocity).	12.0 ms csa.	D = 19.2mc/s
13. (30m width, 0.8depth, 0.2 velocity).	12.0 ms csa	D = 4.8mc/s.

3.3. GPS co-ordinates of sites

GPS coordinates for each site are currently presented using decimal degrees on the UNDC UCAM website. However, many publications require authors to use degrees, minutes , seconds.
GPS coordinates for each sample site can be obtained in two ways –

A.Using: GPS Finder - Garmin Etrex10

This is generally an inaccurate method because to obtain an accurate reading the GPS Garmin device requires contact with a minimum of 8 satellites. In much of Peru and especially in deeply incised valleys or remote locations, such as the Cañete valley, this is not possible. In these situations the GPS co-ordinates calculated for a site may be far away from the actual site. However, this method should be accurate where there is a wide flood-plain and contact with the satellites is possible.
Despite this, aways record the GPS result. This can be corrected using Google Earth later (see Section B below) if accurate site data including photos, are also recorded.

1.Turn on the Garmin Extrex10 by pressing the '***Light***' button.
The screen opens with the cursor positioned over the '***Map***' tab.

2.Use the *toggle* to reposition the cursor over the '***Mark waypoint***' tab and **press** the *toggle* to select it.

3.Read off the '*Longitude*' and '*Latitude*' of the site (waypoint).

4.To obtain the **elevation**, it may be necessary to select the '***Mark waypoint***' tab a second time.

5.Use the *toggle* to move the cursor up to the '***Title'*** at the top of the screen.

Press the *toggle* once and then – letter by letter or number by number – enter the site name.

6.Move the cursor to the bottom of the screen when complete and select '***Done***'.

7.Move the cursor to '***Note***' and enter the site details (as above) as required.

8.Move the cursor to the bottom right of the screen and select '***Done***' – the data record will be stored.

9.To find stored waypoint data, select '***Waypoint Manager'*** on the opening screen and scroll down to find the site/site data required.

B.Using: 'Google Earth Pro'

This allows the GPS co-ordinates for any site to be accurately determined. In the Google Earth Pro program, GPS data is shown automatically in the screen image information bar in the lower right hand corner of the screen, as follows: Imagery date, latitude, longitude, elevation and eye alt.

The longitude and latitude information may be given in one of five ways: i.Decimal degrees; ii.Degrees, Minutes, Seconds; iii.Degrees, decimal Minutes; iv.Universal Transverse Mercator; v.Military Grid Reference System.

These can be selected on screen by going to 'Tools' on the task bar. In 'Tools' go to options and the five options are shown. Click on the option required.

1. Download and **open** up the **'*Google Earth Pro'*** app.

2. Search the required site location.

3. Position the cursor precisely on the site location.

4. Read off the GPS co-ordinates from the bottom of the screen.

5. Read off the **elevation** from the bottom of the screen.

Section 4: LABORATORY TESTS

Chemical tests for components that degrade quickly need to be carried out as soon as possible after the collection of samples. Alkalinity is best tested just after the collection of the sample. Nitrate tests must be done within 48 hours of the sample collection as long as proper storage conditions (acidified with 99.9% grade HNO_3, at 4°C) are provided.

For practical reasons, it is recommended that both tests are carried out at the end of each day. Samples should be collected in bottles filled to the tip leaving no head space in them.

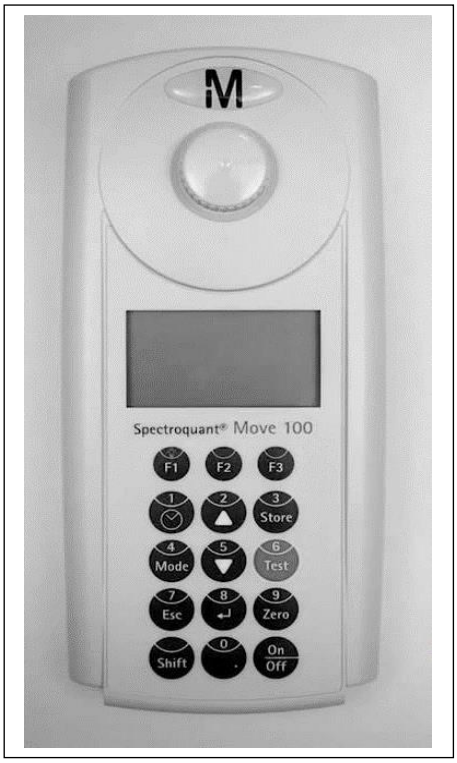
Safety: Always wear gloves, safety glasses and a Lab.coat during the tests. Refer to labels for chemical content and read the risk assessments for safe handling.

4.1. Nitrate Test

Nitrate concentrations in water samples are analysed using a spectrophotometric method. The change in colour is due to the formation of a red-nitro compound, as a result the reaction between sulphuric acid, nitrate ions and a benzoic acid derivative is measured.

***Measurement unit: mg/l NO_3-N and mg/l NO_3**

Equipment & Materials: Spectroquant Move 100; Filter unit & filter papers; Tweezers; Distilled water; Nitrate standard solution; Pipette and pipette tips; Test tube holder; Nitrate cell test kit (cell tests & NO_3-1K powder); flat head screwdriver; CC20 (R-1) solution;



Check and take action:

*Battery Life – replace batteries (4 x AA); flat head screwdriver.

*Dust on the meter – carefully wipe with a wet tissue but do not allow dust to enter the cell compartment.

*Wave length issues – if in doubt, check before the field visits using colour standards.

Equipment set up:

-Insert the test tube holder and align it with the arrow on the holder with the arrow on the base.

Safety: please visit -

http://www.merckmillipore.com/GB/en/product/msds/MDA_CHEM-114542?Origin=PDP

Sample preparations

***Blank samples –**

- For each test batch (one per day) run a blank sample using **distilled water** (provided in blue cap plastic pointed tube).

- Use 1.5ml of distilled water.

***Quality checks –**

- For each test batch (one per day) run a standardisation check using the **standard CC20 solution**.

- Use 1.5 ml of CC20 solution.

***Water samples –**

-Filtered river water samples collected at the river can be used without further treatment.
-Use 1.5ml of filtered water sample for this test.

Sample testing:

A.Reaction for nitrates using a Merck cell kit:

- In **each of 3 cell test tubes** from the kit, **add** one level micro-spoon of NO_3-1K powder to a cell test tube (the temperature of the tube must be in the range 15˚-25˚C) and **shake vigorously** for **one minute**. After shaking any remaining undissolved material will not affect the test.

- **Blank test:** pipette 1.5ml (2 x 750 micro-litres using a pipette) of distilled water to the cell test tube (See Pipette use instructions) without touching the sides of the test tube, if possible.

- Tightly cap the test tube and **gently shake** the test tube, holding the cell test tube by its cap.

NB. the cell test tube will become **very hot.**

- Leave to rest for a minimum of **ten minutes** in a test tube holder (and prepare next sample for testing).

- **Standard test: repeat** for one nitrate 'standard' by adding 1.5ml of CC20 (R-1) to another test tube.

- River water sample: repeat for all river samples by adding 1.5ml of water from each site to the respective cell test tubes.

- The colour of the water in the test tubes will change from colourless to pink / light red depending on the nitrate concentration. **After 10 minutes** of reaction time, use the Move 100 to read the concentration (see below). All tests must be completed within 60 minutes.

B.Reading the colour change Spectroquant Move 100:

- Turn on the Spectroquant Move 100. All potential tests are displayed on the screen (including nitrates) and have a number.

- If the method number is not known, **scroll down** (Key no.5) to search for the required test (ie.14542 for nitrate – check Nitrate test kit box) and then **select** the correct code number (ie.320).

Note: once the method number is known, the method number can be entered directly using the shift key rather than needing to scroll down each time to the required test.

- Press 'enter' (Key no.8) once the required test has been selected.

-An automatic *'10 minute'* countdown appears on the screen. Once complete, start to undertake the analysis.

- Wipe the **Blank** cell test tube (do first) to ensure that it is clean and **place** it in the Move 100 test tube holder, with the two black squares on the test tube aligned with the arrow on the holder.

- Depress firmly and **cover** with the cap so **no light** can enter.

- Press 'enter' **twice**, then the 'No.9 zero' button when prompted to do so on the screen and follow the instructions.

- When the screen displays '**Test**', **remove** the prepared 'Blank' and **insert** the prepared '**Standard**' cell test tube.

- Press the '**red/green**' test button and then read off the result.

- Up and down arrows change the units: NO_3 (appears first) and then $N0_3$-N (shift up – button No.2 - to obtain).

NB. The '$N0_3$-N Standard' value must be in the range 9.0 +/- 0.9. If it isn't, then the test may need to be redone.

- Remove the 'Standard' sample.

- **Insert** the first '**Water**' sample and **press** '**Test**' twice and read off the result and so on for the other water samples, if more samples are being tested.

<u>Pipette use</u>

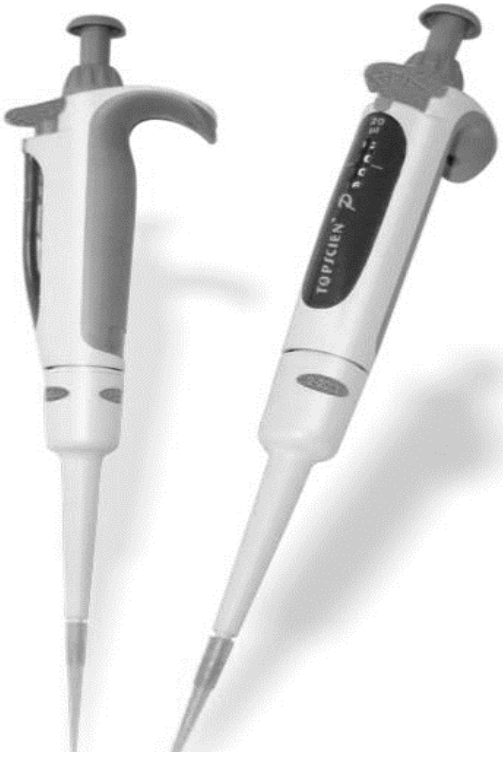
-Add a **new** pipette tip at the start of each test involving a different sample, or liquid.

-Set the volume of liquid required on the revolving counter by **turning** the button at the end. The counter can then be locked using the clip adjoining the counter (for some pipettes only).

-Depress the button to the first position and then place the pipette in to the liquid. The pipette will then draw up the required amount of liquid automatically.

-To release the liquid in to a test tube, **depress** the button slowly, all the way down (to the second position).

-At the end of use, **eject** the pipette tip by depressing the button on the front/above the counter.



4.2. <u>Titration Alkalinity Test</u>

***Method:** Titration - to identify colour change at pH 8.3 (pink to colourless) and at pH 4.5 (green to pink) in the sample.

***Measurement unit: mg/l of calcium carbonate**

***Equipment & Materials:** Digital Titrator; Titrator cartridges (1.6N & 0.16N); Phenolpthalein powder sachet; Bromcresol /Methyl powder sachet; 250ml flask; Distilled water; 100ml measuring cylinder;

***Sample collection:** collect 100ml of **filtered** water.

***Equipment set up:**

-Insert a cartridge in to the Titrator and twist 90 degrees to lock the cartridge in place.

-The cartridge can be used until it is empty.

Note: the cartridge contains sulphuric acid (H_2SO_4).

-Remove cartridge cap and insert detachable end tube.

Note: this must be changed if the cartridge is changed to a different concentration.

-Press in the sliding button and slide along shaft to expel any air in the detachable tube.

Note: at this point any drops of liquid must not be allowed to enter the water sample.

Note: there is a danger of acids shooting out of the detachable tube at this stage.

-For titration, first **zero** the reading using the large dial and then **turn** the button at the end of the titrator to dispense the sulphuric acid (H_2SO_4).

-Once the test is complete, **use** the large dial to return the counter to zero.

***Equipment use:**

-Use measuring cylinder to accurately measure 100ml of **filtered** water and transfer into the 250ml flask.

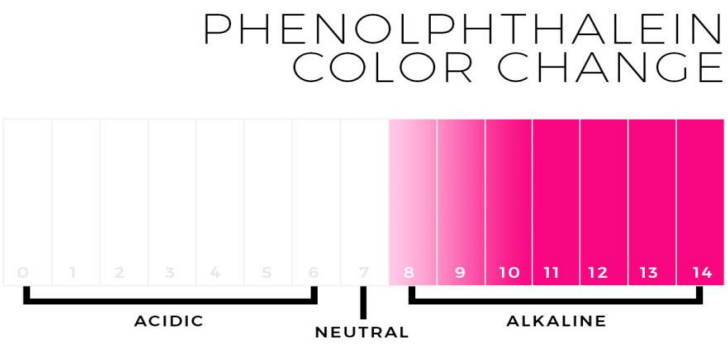
-Begin with the **1.6N** (high concentration) cartridge in the titrator unless the site is known to be especially acidic in which case use the 0.16N (low concentration).

***Test 1: Phenolpthalein test** –

-Empty the P.sachet in to the 100ml water sample and **shake gently** for a moment until completely **dissolved**;

Note: if the water goes even **slightly pink**, this indicates a high level of alkalinity (pH 8.3+) – start titration. See instructions below (Point 3).

-If there is **no** change in colour, the water sample remains transparent, then proceed to Test 2.



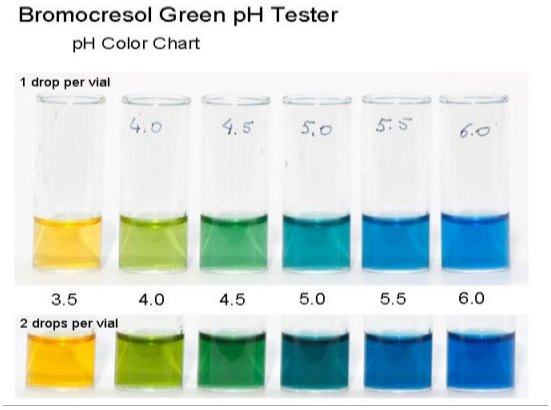
***Test 2: Bromcresol green / Methyl red test** –

- **Add** the Bromcresol sachet to the same water sample and **shake gently** for a moment until completely dissolved.

Note: the sample is most likely to turn **green** (pH 4.5+). Start titration. See instructions below (3).

However, if the sample pH is **low** (pH <4.5) it will turn pink (see '**Result**' below). **No need to titrate.**

After this **no** further tests are needed.



***Test 3: Titration -**

- Ensure that the titrator is set to **zero** (0000) and **no** air bubbles remain on the tube.

- Place the end of the titrator in to the flask but ensure that it does **not** enter the water.

- Turn the dial to dispense the sulphuric acid (H_2SO_4) slowly, <u>one drop</u> at a time.

- **Gently shake** the container as the sulphuric acid (H_2SO_4) is added.

- Add the sulphuric acid (H_2SO_4) until the sample changes colour (**1.Phenolphthalein test**: from pink to colourless; **2.Bromcresol green / Methyl red test**: green to light pink until there is **no** longer a green/blue tint to the sample).

***Result -**

-Read off and record the number displayed on the counter (mg/litre).

Note - if the number displayed on the counter is **<10** by the time the sample turns light pink, then the cartridge must be changed to the 0.16N and Test 2 redone. The counter should **NOT** be set to zero but the score added to the original counter score.

After all tests are complete:

-Dilute the sample and dispose of it in to the **ground** - not in to water.

-Once all tests are complete, **press** and **return** the sliding button to the start.

-Remove the detachable tube and **clean** the outside with distilled water.

-Attach the cap to the cartridge, **twist** and **remove** it from the Titrator. However, the cartridge could be left in the Titrator overnight as long as the cap is on securely if it is going to be used the next day.

Section 5: AT THE END OF THE FIELD WORK

1. Hanna Multiparameter (HI98194)

-immerse the **pH/ORP** electrode in '**electrode cleaning solution**' for 30 minutes.

-clean the electrode with distilled water and put 3-4 drops of '**electrode storage solution**' in the cap and place the electrode (sensor) in the cap.

-when the use of the multiparameter is complete, **place** a little storage solution (1cm) in the storage container to keep all the sensors moist and screw the storage container on to the multiparameter.

-do not leave any water in the main storage container.

-remove batteries, if it is going to be stored for long time.

-clean the exterior of the meter with a tissue wetted with water or 70% ethanol (preferred).

2. Flowmeter

-clean and dry the handheld unit, cables and impellor.

-remove batteries from the control unit and store.

3. OTT MF Pro Flowmeter

-clean with water or 70% ethanol (preferred), and dry, especially the handheld unit, cables and impellor.

-remove batteries from the control unit and store.

4. Geotech pump

-check that all parts are in the case.

-clean the equipment with a wet tissue for dust deposits and clean the case, if necessary.

NB.if the pump is being returned to UCAM, the battery should be left securely stored in Peru but it will then need to be collected prior to the start of the next trip.

5. Titrator

-clean with a wet tissue to remove any dust.

-check that the cartridges are capped and that the caps are fixed tightly.

-place the indicator pillows in the appropriate bags with the correct labels.

6. Spectrometer Move 100

-clean with a wet tissue to remove any dust.

-used cells must be sent for chemical waste disposal in the container which contains a hazard guide for their safe disposal.

-unused cells should be stored away from sunlight and at 15-25°C for use on the next field visit.

7. HDPE bottles

-clean the HDPE bottles by soaking in 1% HCl acid for 2-4 hours, if available.

-and/or **wash** with plenty of distilled water until pH7.

-dry and store away from sunlight and dust for the next field visit (preferably in a polythene bag).

8. 'Inventory sheet' in the 'Check list' Excel file

-complete the 'Inventory sheet' in the 'Check list' Excel file.

-include the quantities and quality of each piece of equipment and chemical.

-note any items that need replacing and the quantities needed in the right hand column, for planning the next field visit.

9. Bottles and tubes for labs

-prepare bottles and tubes for sending to the appropriate labs by separating them according to the relevant tests and site numbers.

Section 6: GLOSSARY OF TERMS

1. Water Quality Parameters

***Alkalinity:** the ability of water to absorb H^+. In other words, it is a measure of water's capacity to neutralize acids = acid neutralizing capacity. Without this acid-neutralizing capacity, any acid added to a stream would cause an immediate change in the pH.

Alkalinity is the sum of the molar equivalent of the anions that will react with H^+ minus the molar equivalent of H^+ already present in the water. Generally, this equates to the amount of carbonate and bicarbonate ions in the water and so carbonate alkalinity typically represents alkalinity.

Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. It is one of the best measures of the sensitivity of the stream to acid inputs. It is measured in mEq/l of $CaCO_3$. High enough alkalinity is really important for the success of freshwater species. Most river water falls between 100-200 mg/l $CaCO_3$.

***Chemical oxygen demand (COD):** indicative measure of the amount of oxygen consumed by reactions in a measured solution. The most common application of COD is in quantifying the amount of oxidizable pollutants which will reduce available oxygen and, consequently, the quality of water for aquatic life.

The *COD* concentrations in surface *water*s ranges from 20-200 mg/l depending on the level of contaminants. Treated sewage water is discharged in the range 75-100 mg/l.

It is commonly expressed as mass of oxygen consumed over volume of solution in milligrams per litre (mg/l).

***Conductivity:** a measure of water's capability to pass electrical flow determined by the concentration of ions present. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulphides and carbonate compounds.

Dissolved salts and other inorganic chemicals conduct electrical current. As the salinity increases the conductivity increases. Organic compounds, such as sugars, oils, and alcohols, do not form ions that conduct electricity. In most cases, conductivity is positively correlated with Total Dissolved Solids (TDS).

Conductivity is measured in micro-siemens per centimetre (µS/cm) and reported as conductivity at 25°C. Distilled water should be in the range 0.5-3.0 µS/cm. Freshwater streams range between 50 to 1500 µS/cm but, ideally, should be in the range 150 to 500 µS/cm to support diverse aquatic life. High quality deionized water should be a maximum of 0.5 µS/cm at 25 °C, while typical drinking water is in the range of 200 - 800 µS/cm, and sea water is about 5 S/m (or 50,000 µS/cm).

***Dissolved oxygen (DO):** a complex measure of how much oxygen (O_2) is dissolved in water, expressed as either a percentage of a theoretical maximum or an absolute amount in mg/l. Oxygen enters water by diffusion from the atmosphere, aeration as it falls over rocks and waterfalls, and as a product of photo-synthesis and winds. DO levels are determined by temperature, atmospheric pressure, salinity, and pH.

DO levels determine the suitability of water bodies for life. As DO levels drop below 5.0 mg/l, aquatic life is put under stress and below 2mg/l produces hypoxia in fish. At high concentrations, super-saturated water (above 115-120%) is also unsuitable for life. DO concentrations in surface seawater is typically 6-10 mg/l.

***Hardness:** is a measure of the mineral (inorganic) content of the water, principally, the amount of dissolved calcium and magnesium; the greater the amount, the harder the water. Generally, hard water reduces the toxicity of trace metals to aquatic life; some metal ions form insoluble precipitates and are not available to organisms.
Water hardness is usually expressed in milligrams per litre (mg/l) of dissolved calcium and magnesium carbonate expressed as equivalent of calcium carbonate and measured in mEq/l of $CaCO_3$. An acceptable level range for water hardness is 100-300ppm. Hard water is not a significant health risk. It can cause mineral build-up in plumbing, fixtures, and water heaters, and poor performance of soaps and detergents.

***Oxygen Reduction Potential (ORP):** is a measure of the cleanliness of the water and its ability to break down contaminants.
ORP is a measure of the tendency of a chemical species to acquire electrons from or lose electrons to an electrode and thereby be reduced or oxidised, respectively. Redox potential is measured in volts (V), or millivolts (mV). Each chemical species has its own intrinsic redox potential; for example, the more positive the ORP, the greater the species' affinity for electrons and tendency to be reduced. ORP can reflect the antimicrobial potential of the water.
The recommended ORP level for pools and spas is 650-750mV – at this level pathogens will be killed instantly. At ORP levels below 500 mV pathogens are killed in an hour or more. Tap water is usually safe as drinking water at 300mV.
ORP readings should be quoted relative to a Standard Hydrogen Electrode (SHE) to be comparable.

***% (atmospheric) Oxygen:** atmospheric **o**xygen concentration is ~21%, but only ~1% oxygen in water. Where air and water meet, this disparity causes oxygen molecules in the air to be directly absorbed into the water. The greater the movement of the water the greater the rate of absorption. Water also shows higher absorbance of oxygen at lower temperatures and greater pressures.
Although water molecules contain an oxygen atom, aquatic organisms living in natural waters need dissolved oxygen (DO) (See above).

***pH** (power of hydrogen)**:** pH is a measure of how acidic/basic water is. The numerical value of pH is determined by the molar concentration of hydrogen ions (H^+). The higher the H^+ concentration, the lower the pH, and the higher the OH^- concentration, the higher the pH. At a neutral pH of 7 (pure water), the concentration of both H^+ ions and OH^- ions is 10^{-7} M. Thus the ions H^+ and OH^- are always paired – as the concentration of one increases, the other will decrease; regardless of pH, the sum of the ions must always equal 10^{-14} M.
In general, water with more free hydrogen ions has a pH lower than 7 and is considered acidic, whereas water that has more free hydroxyl ions with a pH greater than 7 is basic (alkaline). The normal range for pH in surface water systems is 6.5 to 8.5, and the pH range for groundwater is 6 to 8.5.

***Total Dissolved solids (TDS):** TDS is the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per litre of water (mg/l), or parts per million (ppm).
TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, sulphates, bicarbonates and chlorides) and trace amounts of organic matter dissolved in water.

Maximum TDS levels recommended by the WHO is 300ppm.The higher the TDS, the higher the conductivity and the lower the pH. If the water contains beneficial minerals, 150-250 ppm is optimal for life.

The TDS changes the mineral content of water (rivers),high levels of TDS often harm aquatic species. Also, dissolved salts can dehydrate the skin of aquatic animals, which can be fatal.

***Total Nitrogen (TN):** is the sum of nitrate (NO_3), nitrite (NO_2), organic nitrogen and ammonia (all expressed as N). The nitrogen cycle is the means by which atmospheric nitrogen becomes available to living organisms. Nitrogen is essential for life, but excess nitrogen causes eutrophication in natural water and a danger to life. Water quality data suggests that appropriate reference levels for TN range from 0.12 to 2.2 mg/l.

***Total Phosphate (TP):** is a measure of all the forms of phosphorus, dissolved and particulate.TP is a good way to measure phosphorus in lakes because it includes both ortho-phosphate and the phosphorus in plant and animal fragments suspended in lake water. TP levels are more stable and an annual mean can indicate the water quality and trophic state of a lake. Phosphorus is usually considered the "limiting nutrient" in aquatic ecosystems, in other words, changes in phosphorous concentration have greater impacts on productivity than changes in other nutrient concentrations.

The natural levels of total phosphorus in water are generally less than 0.03 mg/l while the natural levels of phosphate usually range from 0.005 to 0.05 mg/l.

***Turbidity:** turbidity is a measure of the degree to which water loses its transparency due to the presence of suspended particulates. The more total suspended solids (TSS) in the water, the murkier it is and the higher its turbidity. Turbidity is another good measure of water quality; the higher the turbidity, the lower the water quality for both human consumption and aquatic life. Turbidity is usually measured in nephelometric turbidity units (NTU). This is an optical measurement of the amount of light scattered by suspended materials, when a light is shone through a water sample. The higher the intensity of scattered light, the higher the turbidity. Typically, turbidity levels are highly variable by season, local geology, water flow and weather events. During a low-flow period, most rivers and lakes are fairly clear with a turbidity reading below 10 NTU.

***Water temperature:** a measure that determines which species thrive in any body of water. There is an inverse relationship between dissolved oxygen and temperature; warm water holds less dissolved oxygen than cold water, and may not hold sufficient DO for aquatic life. Some compounds are also more toxic to aquatic life at higher temperatures. Fluctuations in water temperature have a significant impact on life.

2.Water chemistry

***Anions & Cations:** an ion is an atom or molecule that has a net electrical charge. Since the charge of the electron (considered negative by convention) is equal and opposite to that of the proton (considered positive by convention), the net charge of an ion is non-zero due to its total number of electrons being unequal to its total number of protons.

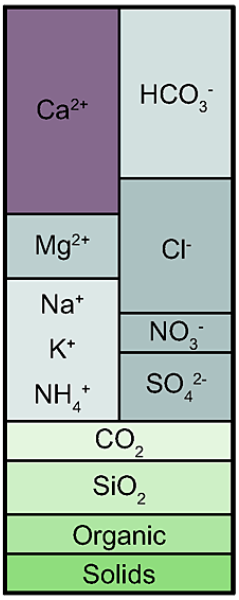
A **cation** is a positively charged ion, with fewer electrons than protons, while an **anion** is negatively charged, with more electrons than protons. Cations and anions attract each other because of their opposite electric charges, and readily form ionic compounds.

The most abundant **cations** present in water are calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K); the most abundant **anions** are bicarbonate (HCO_3), chloride (Cl), and sulphate (SO_4).The dominant dissolved ion must be greater than 50% of the total.

Water is a compound of hydrogen and oxygen that results from the combustion of hydrogen. It is an excellent solvent and, consequently, natural water is not chemically pure; containing dissolved minerals, salts and organic compounds and also disperse and colloid disperse substances, like gases, in varying concentrations and compositions. Water contains different proportions of the following ions, depending on the source of the water:

Cations

- Calcium [Ca^{2+}]
- Magnesium [Mg^{2+}]
- Sodium [Na^{+}]
- Potassium [K^{+}]
- Ammonium [NH_4^{+}]
- Iron [$Fe^{2+/3+}$]
- Manganese [Mn^{2+}]



Anions

- Hydrogen carbonate [HCO_3^{-}]
- Chloride [Cl^{-}]
- Nitrate [NO_3^{-}]
- Sulphate [SO_4^{2-}]

Gases / Solids

- Carbon dioxide [CO_2]
- Oxygen [O_2]
- Silicate [SiO_2]

***Coliformes:** coliform bacteria contain the enzyme B-galactosidase and are a commonly used indicator of the sanitary quality of water. Coliforms can be found in the aquatic environment, in soil and on vegetation. While coliforms themselves are not normally the cause of serious illness, they are used to indicate that other pathogenic organisms of faecal origin may be present including disease-causing bacteria, viruses, or protozoa and many multi-cellular parasites.

Escherichia coli (*E.coli*) is a coliform with an incubation period of 12-72 hours and an optimal growth temperature of 37°C. Unlike the general coliform group, *E. coli* are almost always of faecal origin and their presence is thus an effective confirmation of faecal contamination. Most strains of *E. coli* are harmless, but some can cause serious illnesses in humans.

***Metals:** many different metals can be found in water. The most dangerous are '*heavy*' metals, including arsenic, cadmium, chromium, copper, lead, mercury, and selenium.

Arsenic: occurs in an organic form, which is harmless to humans, and an inorganic form, which can have major health impacts.

Long-term exposure to inorganic arsenic is linked to higher risks of lung, bladder, skin, liver, kidney, nasal passages, and prostate cancer. Other effects include thickening and discoloration of the skin, nausea, stomach pain, vomiting, diarrhoea, etc.

Cadmium: is a naturally occurring metal found in low concentrations but in fairly high levels in sewage sludge.

It is a non-essential element for aquatic life which is, potentially, harmed by it. It has been shown to cause toxic effects to the kidneys, bone defects, high blood pressure, and have reproductive system impacts.

Chromium: doesn't occur naturally in elemental form, but chromium compounds can be found in water in trace amounts.

Trivalent chromium is an essential trace element for humans - it removes glucose from blood, and it also plays a vital role in fat metabolism. However, hexavalent chromium is extremely toxic and is known for its genotoxic carcinogens. It can cause allergic and asthmatic reactions, diarrhoea, stomach and intestinal bleedings, cramps, and liver and kidney damage.

Copper: commonly found in aquatic systems, originating from both natural sources such as geological deposits, volcanic activity, and the erosion of rocks and soils; and anthropogenic sources such as, mining activities, agriculture, sludge from sewage treatment works, and pesticides.

Copper is an essential nutrient at low concentrations, however, at higher concentrations copper is toxic to aquatic life. It can lead to adverse effects on survival, growth, reproduction, brain function, blood chemistry, and metabolism.

Lead: a toxic heavy metal, not usually found naturally in water.

Exposure to lead can lead to premature birth, delayed physical and mental development in babies and cause learning disabilities. Accumulation of lead in adults can cause high blood pressure and kidney problems and may also cause anaemia, strokes, damage to the nervous system, and cancer.

Mercury: a naturally occurring, highly toxic metal and potent neurotoxin.

Scientists have found high levels of mercury accumulation in a wide range of wildlife species, causing dangerous reproductive and neurological problems. It impacts the function and development of the central nervous system in both people and wildlife.

Mercury bioaccumulates, which means that it increases in concentration with each step up in the food chain. When people consume large amounts of fish that contain mercury, they may experience neurological and gastrointestinal problems.

Selenium: a naturally occurring element present in sedimentary rocks, phosphate deposits and soils. Selenium can enter surface water through weathering and erosion, or it can also be released during mining related activities, and irrigation for agriculture.

In small amounts selenium is an essential element for animals, but at higher concentrations is toxic. It bioaccumulates in the aquatic food chain and chronic exposure in fish and aquatic invertebrates can cause larval deformity or mortality. Selenium is also toxic to bird species that consume aquatic organisms containing excessive levels.

***Pesticides:** chemicals designed to control pests (and weeds)and can contain sulphur, chlorine, nitrogen, phosphorus, and bromine as well as heavy metals such as copper, arsenic, lead, and mercury. Pesticides include all of the following: herbicides, insecticides (including insect growth regulators, termiticides, etc), insect repellents, antimicrobials, and fungicide. The most common of these are herbicides which account for approximately 80% of all pesticide use, designed to protect plants/crops from weeds, fungi and insects.

Water pollution is caused by the improper use of pesticides that introduces chemicals into water, changing its properties and posing a threat to human and aquatic life.

3.Hydrology

Endorheic drainage: a closed-system **drainage basin** that retains water and allows no outflow to other external bodies of water, such as rivers or oceans, but converges instead into lakes or swamps, permanent or seasonal, that equilibrate through evaporation.

Exorheic drainage: an open-system drainage basin in which water drains to the sea. That is, outside the drainage basin. Such basins present many complex elements and characteristics throughout the water cycle of their entire system.

***Lentic:** refers to standing, non-flowing water such as water in pools, ponds and ditches.

***Lotic:** refers to water that is flowing such as water in streams and rivers.

4.Geology

Carbon flux: the amount of carbon exchanged between Earth's carbon pools - the oceans, atmosphere, land, and living things - and is typically measured in units of gigatonnes of carbon per year (GtC/yr).

Cation exchange: ion exchange in which one cation (such as sodium or hydrogen) is substituted for one or more other cations (such as calcium and magnesium in hard water).

Chemical species: a chemical substance or ensemble, composed of chemically identical molecular entities that can explore the same set of molecular energy levels on a characteristic or delineated time scale.

Denudation: the processes of erosion, leaching and reducing the mainland due to removal of material from higher to lower altitudes like river valleys, lakes and seas with a permanent filling of low lands.

Dissolution: the dissolving of rocks such as rock-salt (halite), gypsum and limestone (including chalk) producing features such as caves, sinkholes and large springs, creating a landscape known as *karst.*

Dolomitic: a sedimentary carbonate rock that contains a high percentage of the mineral dolomite, $CaMg(CO_3)_2$.

Oxidation: the loss of electrons during a reaction by a molecule, atom or ion.

Redox: is a type of chemical reaction in which the oxidation states of atoms are changed; characterized by the actual or formal transfer of electrons between chemical species, most often with one species undergoing **oxidation** while another species undergoes **reduction.**

Reduction: a gain of electrons or when the oxidation state of an atom, molecule, or ion decreases.

DATA RECORDING SHEET / RECORD de DATOS	
Date / Fecha:	**Time / Hora:**
Site Name / Nombre del sitio:	**GPS: (S)** **(W/O)**
Site code / Codigo del sitio:	**Elevation / Altitúd (metros):**

Air pressure (Presión de la atmosfera) (mbar):
Air temperature (Temperatura del aire) (˚C):

Water data / Datos del agua	**1**	**2**	**3**	**4**	**Av.**
pH					
Water temperature / Temperatura del agua (˚C)					
Conductivity / Conductividad (µ/cm)					
TDS (ppm)					
ORP (mV)					
Dissolved Oxygen / Oxígeno Disuelto (mg/l)					
Dissolved Oxygen / Oxígeno Disuelto (%)					

River data / datos del río	**1**	**2**	**3**	**4**	**5**	**Av.**
Width /Ancho (metros)						
Profundidad (metros)						
Velocity / Velocidad (m/s)						
Water colour / Color del agua:						
River bed sediment types / Tipos de sedimentos del lecho del río:	***Clay/Arcilla*** ***Sand/Arena*** ***Cobbles/Piedras*** ***Silt/Limo*** ***Pebbles/Guijarros*** ***Rocks & Boulders/Rocas***					
Principal sediment-riverbed colour / Color principal de los sedimentos:						

Water samples / Muestras de agua:	**Size / Tamaño (ml)**
Metals (Filtered) / Agua (Filtrado) ****Add Acid ****	
Aniones + Cationes (Filtered / Filtrado)	
COD / DQO (Unfiltered / Sin filtrar)	
Coliformes (Unfiltered / Sin filtrar)	
Pesticides (Unfiltered / Sin filtrar)	
Other / Otros:	

Sediment samples / Muestras de sedimentos:		No. / Número
River bed / Lecho del río		
River bank / Orilla		
Filter paper	Empty bottle weight / Peso de la botella vacio:	Bottle weight with filtered water / Peso de la botella con agua filtrado:

Other samples / Otras muestras: *algae / algas, plants / plantas, ...*

Field Laboratory Tests / Pruebas del laboratorio del campo		
Alkalinity / Alkalinidad (mg/l $CaCO_3$)	Result / Resultado	
Tester kit in field / en el campo		
Test strips / Tiras reactivas		
Titration / Titración		0.16N o 1.6N

Nitrates/ Nitratos (mg/l NO_3)	Result / Resultado	
Test strips / Tiras reactivas		
Spectroquant		

Observations / Observaciones: *geology / geología, contamination / contaminación, ...*

Data collectors / Recolectores de datos	Person / Persona	Universidad
River characteristics / Características del río		UCAM / UNDC
Water characteristics / Características del agua		UCAM / UNDC
Water samples / Muestras de agua		UCAM / UNDC
Sediment samples / Muestras de sedimentos		UCAM / UNDC
Photos / Fotos		UCAM / UNDC
Drone footage / Imágenes con drones		UCAM / UNDC

Section 8: RISK ASSESSMENTS

Risk assessments ensure that everyone involved in the fieldwork and investigation are aware of the risks associated with the procedures and guidance is given on how to minimize the risks. Please read ALL the risk assessments before you start work.

This section includes risk assessments regarding water sampling, preservation and field tests only. General fieldwork risk assessments can be found as a separate document, ask the field coordinators.

List of risk assessments included:

WCR01: Calibration of equipment for pH, Electrical Conductivity, Dissolved Oxygen, ORP measurements.

WCR02: Use of *sodium thiosulphate* for preserving water samples for pesticide tests.

WCR03: Testing for nitrates in water samples using Merck Cell Test Kits.

WCR04: Testing for Alkalinity in water samples using a Hach titrator.

WBR01: Water sampling, preservation and testing.